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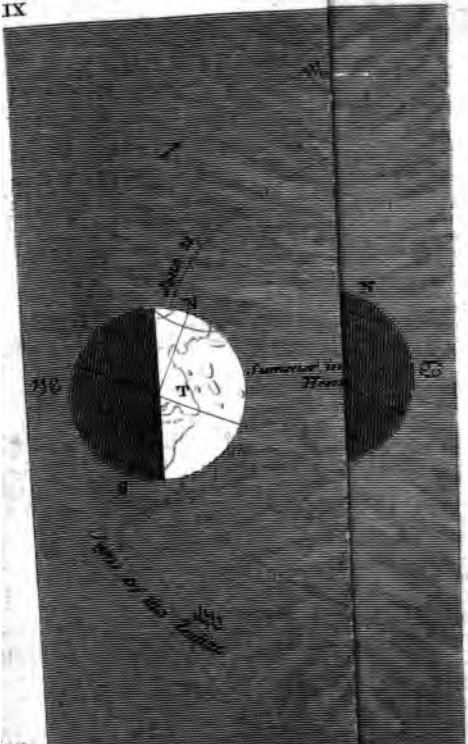


VARIATIONS.

AN EASY

GRAMMAR

OF

NATURAL AND EXPERIMENTAL

PHILOSOPHY:

FOR THE USE OF SCHOOLS.

With Ten Engravings.

BY THE REV. DAVID BLAIR, A. M.
Author of the Class Book, Reading Exercises, &c.

LONDON:

PRINTED FOR RICHARD PHILLIPS, NO. 6, BRIDGE-STREET;
And to be had of all Booksellers.

1807.

(*Price Three Shillings bound.*)

W. Flint, Printer, Old Bailey.

PREFACE.

The Author of the following pages is aware that there already exist several valuable books on Natural and Experimental Philosophy, and he should not have presumed to add to their number except for the purpose of reducing so important a branch of knowledge to the level of the business of schools.

Every instructor of youth must be aware that mere disquisition is of no use in the art of teaching, and that no science can be taught if the student does not *work* or perform operations in it.

A grown person might read all the books which exist relative to any Science, and yet remain totally ignorant of its principles and be as unable to apply them, or reason about them, if he did not patiently commit to memory its axioms, definitions, and leading divisions, and if he did not apply these himself to the practice of the science in which he is desirous to become a proficient. He who only reads *about* a science can be nothing more than a *smatterer*, while

he who commits its terms and elementary principles to memory and applies them by his own act to the various combinations of the science, soon becomes a *master* of it.

Such being the case with persons of mature age, how is it to be expected that young persons who seldom learn any thing by force of reasoning, and who acquire knowledge only by mechanical means, should become proficients except by committing the elementary principles of a science to memory, and exercising themselves in its practice?

In strict conformity with this feeling, the Grammar of Natural Philosophy has been compiled. All the

definitions and elementary principles have been written with a studied brevity so that they may be learnt by rote. With these have been intermixed such easy and familiar Experiments and Illustrations as enable the young student to *work* in each science, and at the same time render its principles intelligible to the lowest capacity. The exercises and questions have been drawn up in such a manner as that in answering them the student may be forced to apply the several experiments, and reflect on what he has previously committed to memory. The Glossary explains many things which could not be introduced agreeably to good method among the definitions. And finally the Plates tend to illustrate the experi-

ments, and render unnecessary some of the apparatus which they represent.

If the Author has not been equally happy in every department, he shall feel it a distinction to be honoured with the observations of intelligent Tutors, and he shall thankfully avail himself in a future edition of every improvement which may be so suggested to him.

He cannot let pass this favourable opportunity to express his sense of the honour which has been rendered to his humble endeavours in the two works which he has already submitted to the public. He alludes to his *Class Book*, and his *Exercises in Reading*, in both of which he laboured diligently to give a popular

feature to useful knowledge, and he has met with his reward in the unparalleled success of his books. The Letters of Approbation which he has received from the heads of public seminaries, the almost universal Adoption of these works by intelligent teachers in every part of the world where the English language is taught, and the actual Sale of nearly TEN THOUSAND copies of each book within a year after its publication, are testimonies of which it has been the fate of few authors to boast.

He hopes the present work will not diminish the reputation he has acquired!

DAVID BLAIR.

Islington,
Aug. 1807.

A

GRAMMAR

OF

NATURAL PHILOSOPHY.

OF MATTER AND ITS PROPERTIES.

1. MATTER is the general name of every thing or substance that has length, breadth and thickness.

2. The inherent properties of all matter are SOLIDITY, DIVISIBILITY, MOBILITY, and INERTNESS.

3. SOLIDITY is the property which every body possesses of not permitting any other substance to occupy the same place with it at the same time.

Illustration 1. If a piece of wood or metal occupy a certain space, before any thing else can take possession of that space, the wood or metal must be removed.

2. Water and even air have this property.

Experiment 1. If some water be put into a tube closed at one end, and a piece of wood be inserted

that fits the inside of the tube very accurately, it will be impossible by any force to get the wooden piston to the bottom of the tube, unless the water is taken away.

2. The experiment may be made with air instead of water.

Corollary. Therefore water, air, and all other fluids, are in a certain space equally solid with the hardest body.

4. *Divisibility* is that property of matter by which its parts may be separated from each other. Of this there can be no end.

Illustration 1. Since matter can never be annihilated by division, so we can never imagine it to be cut into such small particles, that any one of them shall not have an upper and under surface, which may be separated if we have instruments fine enough for the purpose.

2. It would also be absurd to say that the greatest mass has more halves, quarters, or thousandth parts, than the smallest particle of matter.

Experiment 1. If a grain of gold be melted with a pound or 5760 grains of silver, and a single grain of the mass be dissolved in diluted nitric acid, the gold, which is only the 5761st part of a grain, will fall to the bottom and be visible.

2. A grain of gold may be hammered by the gold-beaters to such a degree of fineness, that the two millionth part of the grain can be seen by the naked eye.

3.—In addition to these experiments we may observe that there are animalculæ so small, that many thousands of them taken together are smaller than the point of a needle.

4. The particles of light are still more minute than these, or we dare not open our eyes.

Corollary. From all which it is evident, that matter is actually divisible to a degree much greater than we can imagine: and to which we can set no limits.

5. *Mobility* is that property of matter by which it is capable of being moved from one part of space to another.

Illustration. It is found from experiment and observation, that all matter is capable of being moved if a sufficient force can be applied for the purpose.

6. *Inertness*, or inactivity, is that property of matter by which it would always continue in the same state of rest or motion in which it is put, unless prevented by some external force.

Illustration 1. It is evident that matter, as a stone, can never put itself in motion.

2. Bodies in motion, as a bowl on the ground, or a cannon ball passing through the air, fall from motion to a state of rest, either by the friction of the earth; by the gravity or weight of the body, or by the resistance of the air.

Experiment 1. A marble shot from the fingers would run but a small distance on a carpet: its motion would be continued much longer on a flat pavement; and longer still on fine smooth ice. Here the friction is greatest on the carpet, and least on the ice. If the friction were quite removed, and the resistance

of the air also, the marble once put in motion would continue in that state for ever.

2. If a ball were fired from a cannon with a certain velocity, and there were no resistance from the air, it would circulate round the earth perpetually, and never come to a state of rest. In this manner the moon goes round the earth, although she is as inactive as a stone.

3. If a person were standing in a boat at rest, and the boat be suddenly pushed from the shore, he will be in danger of falling backwards. And if the boat in swift motion be stopped before he is aware, he will fall forwards, because his tendency will then be to continue in the same state of motion.

4. This principle is applicable to the motion on horses or in carriages.

OF ATTRACTION AND REPULSION.

7. BY ATTRACTION is meant the tendency that bodies have to approach each other.

8. There are five kinds of attraction: viz. the attraction of *cohesion*; of *gravitation*; of *electricity*; of *magnetism*; and *chemical* attractions.

9. The attraction of cohesion is that by which the small particles of matter are kept together. By this principle bodies preserve their forms, and are prevented from falling to pieces.

Illus-

Illustration. The attraction of cohesion takes place between bodies only when they are at very small distances from each other.

Experiment 1. If two leaden bullets be scraped very clean, and squeezed together, they will adhere so firmly as to require a considerable force to separate them.

2. If two globules of quicksilver be placed near each other, they will run together and become one large drop.

10. *Capillary* attraction is reckoned a species of cohesion.

Experiment 1. If a small glass tube, open at both ends, be dipt in water, the water will rise up in the tube higher than its level in the bason. The smaller the bore of the tube, the higher will the water rise.

2. Take two pieces of glass five or six inches square, join any two of their sides, and separate the opposite sides with a small piece of stick, so that the surfaces may form a small angle; then immerse them about an inch deep in a bason of coloured water, and the water will rise between the glasses, and form a beautiful curve.

3. A piece of sugar, or spunge, will draw up water or any other fluid upon the same principle.

11. It is, probably, owing to the various degrees of cohesion, that some bodies are hard, and others soft; that some are in a solid, others in a fluid state.

12. REPULSION is a force that is supposed

to extend to a small distance round bodies, and prevent them from coming into actual contact.

13. Where the sphere of attraction ends, a repulsive force begins.

Illustration. The repelling force of the particles of a fluid is but small, and therefore if a fluid be divided, it readily unites again. But, if a hard substance, as glass, or sealing-wax, be broken, the parts cannot be made to adhere, unless they are moistened in one instance, or melted in the other.

Experiment 1. Water repels most bodies till they are wet. A small sewing-needle will swim on a bason of water.

2. Drops of water will roll on the leaves of many vegetables without wetting them.

3. If a ball of light wood be dipped in oil, and put into a pan of water, the water will be repelled from the wood, and will form a channel round it.

14. The attraction of *gravitation*, or *gravity*, is that force by which distant bodies tend toward one another.

15. By gravity, a stone dropped from a height, falls to the surface of the earth; and by it the heavenly bodies are retained in their orbits.

16. The planets gravitate towards the sun, and towards each other, as well as the sun towards them.

17.

17. By gravity, all terrestrial bodies tend towards the centre of the earth.

18. In all places equally distant from the centre of the earth, the force of gravity is equal.

19. The force of gravity is less at the equator than it is at the poles, because the equatorial diameter, is 34 miles longer than the polar diameter.

20. The force of gravity is greatest at the earth's surface, from whence it decreases upwards and downwards.

21. It decreases upwards as the square of the distance from the centre, and downwards simply as the distance.

Illustration. At *double* the distance from the centre *above* the *surface*, the force of gravity would be only ¼th of what it is at the surface, and at three times the distance the force would be only one-ninth. At the distance of half a semi-diameter from the *centre*, the force would be only one-half what it is at the surface: at one-third of the semi-diameter, the force would be one-third, and so on.

OF MOTION.

22. Motion is a continued and successive change of place.

23. Nothing can be produced or destroyed without motion, and every thing that happens depends upon it.

24. We are chiefly concerned with two kinds of motion: 1. That by which an entire body is transferred from one place to another. 2. The motion of the parts of bodies among themselves.

Illustration. By the first kind of motion, a heavy body falls to the surface of the earth; a carriage moves, and a ship sails. It is by the second that plants and animals grow, and the compositions and decompositions of bodies take place.

Experiment 1. Take a decanter of clear water, and hold it in the rays of the sun, and you will see how the light particles contained in it are in perpetual motion.

2. Let the rays of the sun pass through a small hole in a window shutter, and you will observe the particles, floating in the atmosphere, are in constant motion, of whose existence you were not before aware.

25. There are several things to be noticed with regard to motion: 1. The force which impresses the motion.—2. The quantity of matter in the moving body.—3. The velocity

city and direction of motion.—4. The space passed over by the moving body.—5. The time employed in going over this space. And, 6. The force with which it strikes another body that is opposed to it.

26. Every body, by its inertness, resists all change of state; therefore to put a body in motion, there must be sufficient cause.

27. The causes of motion are called motive powers: these are the action of men and other animals, wind, water, gravity, the pressure of the atmosphere and steam.

28. The velocity of motion is estimated by the time employed in moving over a certain space, or by the space passed over in a certain time. The less the time, and the greater the space moved over, the greater is the velocity.

29. To ascertain the degree of velocity, the space run over must be divided by the time.

Example 1.— If a ship sail at the rate of 12 miles in an hour, or sixty minutes, then the velocity is equal to one mile in five minutes.

2.—If two persons set out together on a journey, and one walk 2½ miles, and the other walk 5 miles an hour, the velocity of the latter will be double that of the former.

30. To measure the space run over, the velocity must be multiplied by the time.

Illus-

Illustration. It is evident that if either the velocity or the time be increased, the space run over will likewise be increased.

Example. If the velocity be doubled, then the body will move over twice the space in the same time: if the time be twice as great, then the space will be doubled: but if the velocity and time be both doubled, then will the space be four times as great.

31. A body in motion must every instant tend to some particular point.

32. It may tend always to the same point, in which case the motion will be in a straight line.

33. It may be continually changing the point to which its motion is directed; and this will produce a curvilinear motion.

34. If a body is acted upon only by one force, or by several forces in the same direction, its motion will be in the same direction in which the moving force acts.

Example. The motion of a boat, which a man, at a given place, draws to him with a rope, is of this kind.

35. If two or more forces, differently directed, act upon the same body at the same time, as it cannot obey them all, it will move in a direction somewhere between them. This is called the composition and resolution of motion.

Illustration. Suppose a body A (Plate 1, fig. 4) to be acted upon by another body in the direction A B,

B, while at the same time it is impelled in the direction A C, then it will move in the direction A D. If the lines A B, and A C, be made in proportion to the forces, and the lines C D, and D B, be drawn parallel to them, so as to complete the parallelogram, then the line which the body A will describe, will be in the diagonal A D, and the length of this line will represent the force with which the body will move.

Example 1. There are many instances in nature, of motion produced by several powers acting at the same time. A ship driven by the wind and tide is one: so also is a paper kite acted upon by the wind in one direction, and by the string in another.

2. A ball fired from a cannon is acted upon by two forces, the one is that occasioned by the powder, the other is the force of gravity.

36. *Accelerated* motion, is that in which the velocity is continually increasing.

37. *Uniformly accelerated* motion, is that in which the velocity increases equally in equal times.

Example 1. The increasing velocity with which a body falls to the earth, is an instance of accelerated motion, which is caused by the constant action of gravity.

2. The cannon ball is acted on by a single impulse of the powder, and the accelerating force of gravity, it therefore describes a curve. This is the foundation of the art of gunnery.

38. Motion is said to be *retarded*, if its velocity continually decreases; and to be *uniformly retarded*, if its velocity decrease equally in equal times.

39. The velocities of falling bodies are in proportion to the spaces run over.

40. The velocities, and also the spaces passed over by falling bodies, in each instant, increase as the odd numbers 1, 3, 5, 7, 9, &c.

Illustration. The space described by a body falling from A, fig. 2 in the time expressed by A B, with an uniformly accelerated velocity, represented by the lines D E, of which the last degree is expressed by B C, will be represented by the area of the triangle A B C. If gravity ceased to act, the space passed over in the next portion of time B F, would be measured by B F, multiplied into the velocity B C, that is, by the rectangle B C G F, which is equal to twice the triangle A B C. But if gravity still acts, then the triangle C G H, must be added; of course the body moves over three times the space in the second instant that it did in the first. The next portion of time it would move over five times the space represented by the two rectangles and triangle, and in the fourth portion of time, seven times, and so on in arithmetical progression.

Corollary. It follows that the *whole* space described, is as the square of the time; that is, in twice the time it will fall through four times the space; in thrice the time, nine times the space, &c. See the figure.

Example. In the first instant there is one space run through; at the end of the second, there are four; at the end of the third, nine, and so on.

41. It is found by experiment, that a body falling from a height, moves at the rate of about 16 feet in the first second of time; in the next 48, in the third 80, in the fourth 112 feet, and so on.

Corol-

Illustration. The whole space will be as 16 : 16 + 48, or 64 equal to 16 × 4, or the square of 2 : 16 + 48 + 80, or 144 equal to 16 × 9, or the square of 3 : 16 + 48 + 80 + 112, or 256 equal to 16 × 16, or the square of 4 : and so on.

42. The *force* with which a body moves, or which it would exert upon another body opposed to it, is always in proportion to the velocity multiplied by its weight.

43. This force is called the *momentum* of the body.

Illustration. If two equal bodies move with different velocities, their forces or momenta are in proportion to their velocities.

Experiment 1.—If two equal cannon balls be projected, by different quantities of powder, so that the velocity of the one is double that of the other, then the force or momentum of the former will be double that of the other.

2.—If two stones, one of two pounds and the other of six pounds be hurled with equal velocities, the force or momentum of the latter will be three times greater than that of the former.

Corollary.—In all cases the momenta of bodies must be as the quantities of matter multiplied into the velocities.

CENTRAL FORCES, AND THE CENTRE OF GRAVITY.

44. All motion produced upon a body, by one force only, must be in a right line.

Corollary. Therefore a body moving in a curvilinear direction must be acted upon by two forces at least: and when one of these cease to act, the body will move again in a straight line.

Experiment. A stone in a sling is moved round by the hand, while it is pulled towards the centre of the circle which it describes by the string. But when the string is let loose, the stone flies off in a tangent to the circle.

45. Every body moved in a circle tends to fly off from the centre: this is called the *centrifugal* force.

46. That force by which bodies are drawn towards a centre, and which makes them revolve in a circle, is called the *centripetal* force.

47. The centrifugal and centripetal forces are denominated *central* forces

48. The *centre of gravity* of a body is that point about which all its parts do in any situation exactly balance each other.

49. If a body be suspended or supported by the centre of gravity, it will rest in any position into which it is put.

50. Whatever supports the centre of gravity, bears the weight of the whole body, therefore the whole weight of a body may be considered as centered in this point.

51. The common centre of gravity of two or more bodies, is the point upon which they would rest in any position.

Illustration. If the centres of gravity of two bodies, A, B, fig. 3. be connected by the right line AB, the distances AC, and BC, from the common centre of gravity, C, are inversely as the weight of the bodies A and B; that is, the point C will be as much nearer to A than to B, as A is heavier than B; that is, AC : BC :: B : A.

Experiment. Suppose A to be a ball of 12 pounds, and B to weigh only 4 pounds, and the length AC to be five inches: then BC will be 15 inches: for it will be 5 : BC :: 4 : 12, or $4 + BC = 5 + 12 = 60$, and $BC = \frac{60}{4} = 15$.

52. If a line be drawn from the centre of gravity of a body perpendicular to the horizon, it is called the *line of direction*, because it is the line that the centre of gravity would describe if the body were suffered to fall.

53. While the line of direction falls within the base upon which the body stands, the body cannot fall; but if it fall without the base, the body will tumble.

Illustration. The inclining body ADCD, fig. 4. whose centre of gravity is E, stands firmly, because the

the line ofdirection EF falls within the base. But if the body ABGH be placed upon it, the centre of gravity will be raised to L, and then the line of direction LD will fall out of the base; of course the centre of gravity is not supported, and the whole must fall.

Corollary. This shews the folly of rising up in a coach or boat in danger of oversetting, which raises the centre of gravity, and perhaps throws the line of direction out of the base. Whereas in such a situation the proper course is to slip to the bottom, which brings the line of direction, and consequently the centre of gravity, farther within the base, and diminishes the danger.

54. The broader the base, and the nearer the line of direction is to the centre of it, the more firmly does a body stand.

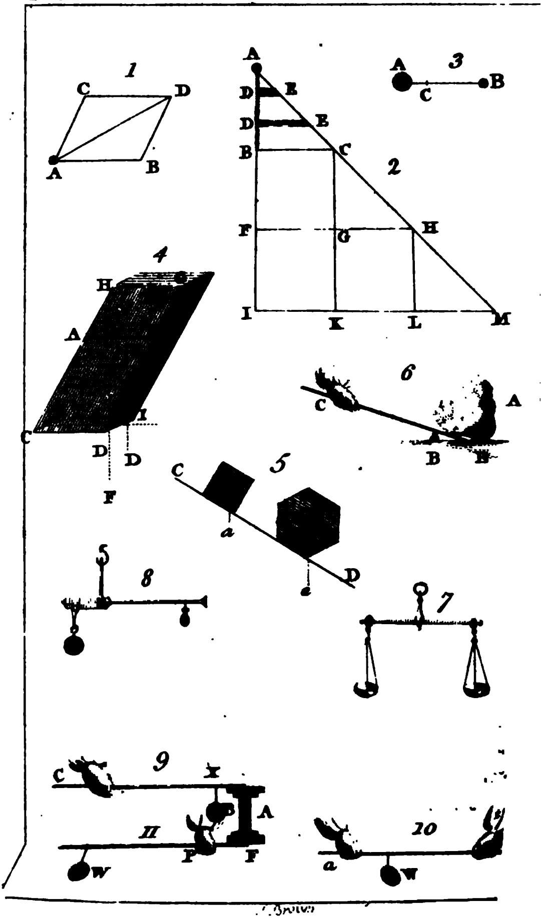
55. The narrower the base of a body, and the nearer the line of direction is to the side of it, the more easily is it overthrown.

Corollary. Hence a sphere is easily rolled upon a horizontal plane; and a narrow-pointed body is with difficulty made to stand.

56. If a plane be inclined on which a heavy body is placed, the body will slide down upon the plane while the line of direction falls within the base; but it will slip or roll down, when that line falls without the base.

Illustration. The body E, fig. 5. having the line of direction Ea within the base, will only slide down; but the line of direction Ba of the body B falling out of the base, that body rolls down the plane.

Expe-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Example 1. When the line of direction falls within the base of our feet, we stand; and most firmly, when it is in the middle; but when it is out of the base, we fall.

2. Rope-dancers are able to perform their feats by knowing how exactly to keep the common centre of gravity, of themselves and their pole, just within the base.

3. We apply this principle in the common actions of life: thus we bend our body forward when we rise from a chair, or go up stairs:—a man leans forward when he carries a burthen on his back; and to the right or left as he carries it on the opposite side.

OF THE MECHANICAL POWERS.

57. The mechanical powers, are simple engines, that enable men to raise heavy weights, move heavy bodies, and overcome resistances, which they could not do with their natural strength alone.

58. Every machine is composed of one or more of the mechanical powers.

59. Three things are always to be considered in treating of mechanical engines: 1, The *weight* to be raised; 2, the *power* by which it is to be raised; and, 3, the *instrument* by which this is to be effected.

60. There are six mechanical powers: viz.

the *lever*; the *pulley*; the *wheel* and *axis*; the *inclined plane*; the *wedge*; and the *screw*.

61. The power of a machine is calculated when it is in a state of equilibrium, that is, when the *power* just balances the *resistance* of the weight.

OF THE LEVER.

62. The *lever* is a bar of iron or wood, supported on and moveable round a prop called a fulcrum.

63. There are three kinds of levers, distinguished according to the different situations of the fulcrum, and the power with respect to each other.

64. In all kinds of levers, the power is to the weight, as the distance of the weight from the fulcrum, is to that of the power from the fulcrum.

65. The lever of the first kind, is when the fulcrum is placed between the weight and the moving power, as in fig. 6.

Illustration. If it be required to raise the stone A, which weighs 1000 pounds, by the strength of a man equal to 100 pounds weight, a lever C E, which rests on the prop B, is placed with one end under the stone, and

and the man presses it down at the other end C. As the man's strength is only equal to the tenth part of the weight of the stone, the arm of the lever B C must be ten times as long as the arm B E, in order that the power and the weight may balance each other.

Experiment 1. A *balance* is a lever of the first kind with equal arms. See fig. 7.

2. The steel-yard, fig. 8, is also the first kind of lever with a moveable weight.

3. A poker in the act of stirring the fire, is a lever of this kind: the bar of the grate upon which it rests, is the fulcrum; the coals, the weight to be overcome, and the hand is the power.

4. To this kind of lever may be referred scissars, pincers, snuffers, &c. which are made of two levers, acting contrary to each other. The fulcrum, in these cases, being the pin which keeps them together.

66. The lever of the first kind is chiefly used for loosening large stones; or to raise great weights to small heights, in order to get the ropes under them.

67. The second kind of lever, is when the fulcrum is at one end, the power at the other, and the weight between them: see fig. 9, where A is the fulcrum, B the weight, and C the power.

Illustration. The advantage gained by this lever is as great as the distance of the power from the fulcrum exceeds the distance of the weight from it: thus if the hand at C be nine times as far from A as the point X on which the weight acts, then the force of one pound at C, will balance the weight B of 9lb.

Experiment 1. This kind of lever shews the reason

why

why two men carrying a burthen, as a cask, upon a pole, may bear unequal shares, according to their strength, by placing it nearer to the one than the other: see fig. 10. Here the weight W is three times nearer to *a* than to *b*, of course *a* would bear three times as much weight as *b*.

2. This is applicable to the case of two horses of unequal strength, where the beam may be so divided, that the horses shall draw in proportion to their respective ability.

3. To this kind of lever may be referred oars, rudders of ships, doors turning on hinges, cutting knives which are fixed at one end.

68. A lever of the third kind, is when the prop is at one end, the weight at the other, and the power applied between them. Here the power must exceed the weight, in the same proportion as the distance of the weight from the prop, exceeds the distance of the power.

Illustration. Let F fig. 11, be the prop or fulcrum, P the power and W the weight; if the distance PF, be only three inches, and W F be 12, then for the hand P to balance the weight of 20 lb. will require a force of 4 times 20, or 80 lb. because the weight is at four times the distance from the fulcrum that the power is.

Experiment 1. A ladder, which is to be raised by the strength of a man's arms, represents a lever of this kind, where the fulcrum is that end which is fixed against the wall, or upon which another man stands; the weight may be considered as at the top part of the ladder, and the power is the strength applied to the rearing of it.

2. The wheels in clock and watch work, may be

be reckoned levers of this kind, because the power that moves them, acts near the *centre* of motion, by a pinion, and the resistance it has to overcome acts against the teeth at the *circumference*.

3. The bones of a man's arm; and the greatest number of the moveable bones of animals, are levers of the third kind. To take the arm, Plate II. fig. 12. as an instance, D, the elbow, is the centre of motion, the power is the muscle inserted at C, about one tenth part as far below the elbow as the hand is, and A is the weight to be raised; the muscle must accordingly exert a power equal to one hundred pounds, to raise a weight of ten pounds.

Corollary. Hence in natural levers the power is disadvantageously situated, owing to the power being so near the centre of motion, but the loss of power is compensated by the beauty and compactness of the limb.

69. What is called a hammer-lever differs in nothing but its form from a lever of the first kind.

Illustration. Let A C B, fig. 13. represent a lever of this kind bended at C, which is the fulcrum. P is the power acting upon the longer arm A C, by means of the cord A D going over the pulley D; and the weight W acts upon the shorter arm C B of the lever. As A C is five times as long as C B, a weight of five pounds at P will balance 25 pounds at W.

Experiment 1. If the shaft of a hammer is six times as long as the iron part that draws the nail, the lower part C resting on the board X as a fulcrum, then by pulling at A, a man will draw a nail with one sixth part of the power that he must use to pull it out with a pair of pincers: in the latter case the nail would move as fast as the hand, but in the former, the hand would move over six times as much space

as the nail during the time of drawing it out of the wood.

Corollary. In all the mechanical powers it will be found, that the advantage gained is in proportion to the space passed over by the moving power.

OF THE WHEEL AND AXIS.

70. The wheel and axis, though made in many forms, consists of a cylinder, and a wheel fastened to it, as in fig. 14. or of a cylinder, with projecting spokes that answer the same purpose as a wheel, as in fig. 15.

71. The advantage gained, is in proportion as the circumference of the wheel is greater than that of the axis: or as the diameter of the wheel is greater than the diameter of the axis.

Illustration. If the diameter of the wheel fig. 14. or the length of the spokes fig. 15, be four feet, and the diameter of the axis only 8 inches, then the power P. of one hundred pounds, or the strength of a man applied to the spokes S equivalent to a hundred pounds, will balance a weight W of six hundred pounds.

In this case, as in the lever, the power will travel over six times as much space as the weight, when the machine is put in motion.

Example 1. To this engine, cranes of all kinds for raising heavy weights, may be referred.

2. Sometimes the axis is turned by a winch fastened to it, which serves for a wheel, and the power gained

gained is in proportion as the winch is larger than the axis.

3. A capstan is a cylinder of wood, with holes in it, into these bars are put to turn it round. The bars are made to act something like the spokes fig. 15.

OF THE PULLEY.

72. The pulley is a small wheel turning on an axis with a rope passing over it. see fig. 16.

73. The small wheel *x* is called a sheeve, and is so fixed to a block *a*, as to be moveable round a pin passing through the centre.

74. Pulleys are either *fixed*, or *moveable*.

75. The fixed pulley gives no mechanical advantage, but is used only to change the direction of a power. By it a man may raise a weight to any height, without moving from the place in which he is, as a stone to the top of a building, otherwise he must ascend with the weight.

76. The moveable pulley represented by *x*, fig. 16. is fixed to the weight, and rises and falls with it, and the advantage gained by it is as 2 to 1; that is, a power exerted by the hand *h* of 10 lbs. will balance a weight W of 20 lbs.

Illustration. The reason of this is evident, for in raisin'

raising the weight one inch, foot, or yard, both sides of the rope must be shortened as much, that is, the hand *h* must move through two inches, feet, or yards, which shews, as before, that the space through which the power moves, must be always in proportion to the advantage gained.

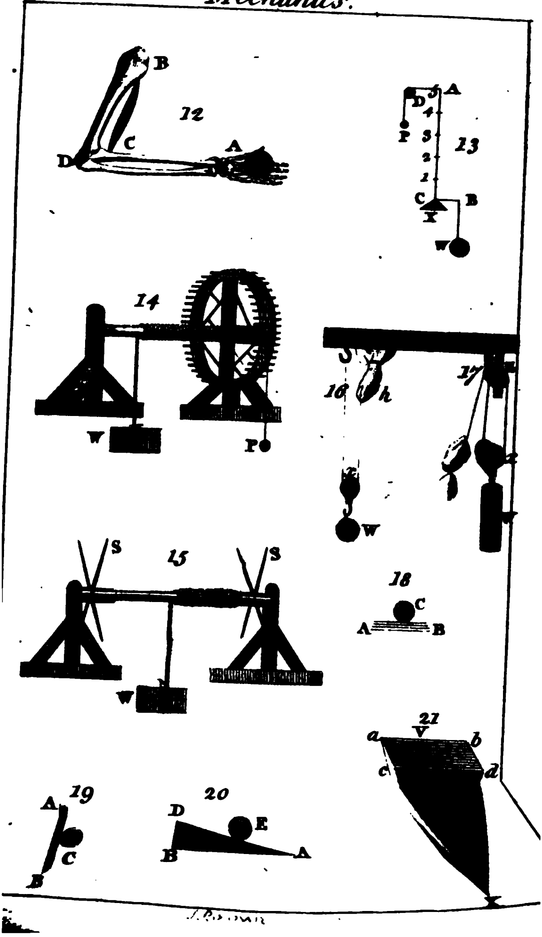
77. When the upper fixed block *z*, fig. 17. contains *two* pulleys, which only turn on their axis, and the lower moveable block *x* contains also two, which turn, and rise with the weight W, the advantage gained is as *four* to *one*.

Illustration. For each pulley in the lower block will be acted upon by an equal part of the weight, and since in each pulley that moves with the weight, a double increase of power is gained, therefore the advantage gained is as *four* to *one*.

78. In general, the advantage gained by pulleys is found by multiplying the number of pullies in the lower block by 2.

Example 1. A weight W of 72 lb. may be balanced with a set of pullies, having four in the lower block, by a power of nine pounds, because 72 divided by 8 gives 9; but in this case the power when put in motion, will pass over 8 times as much space as the weight; that is, to raise the weight one foot, the hand must move over eight feet.

79. A pair of blocks with a rope is called a *tackle*.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OF THE INCLINED PLANE.

80. This mechanical power is merely a plane surface inclined to the horizon, and is used to raise weights from one level to another. Fig. 20.

81. It is often made by placing boards, or earth, in a sloping direction, and is of great importance in rolling up heavy bodies, as casks, wheel-barrows heavy laden, &c.

82. The force with which a body descends upon an inclined plane, is to the force by which it would descend perpendicularly in free space, as the height of the plane is to its length.

Illustration. If the plane A B, fig. 18. be parallel to the horizon, the cylinder C will be at rest on any part of it where it is laid.

If the plane be placed perpendicularly as A B, fig. 19. the cylinder will descend with its whole weight, and would require a power equal to its weight to keep it from descending.

If the plane be inclined to the horizon as A D, fig. 20. and three times the length of the perpendicular D B, the cylinder E will be supported by a power equal to a third part of its weight.

83. The advantage gained by this mechanical power is in proportion as the length of the plane exceeds the perpendicular height.

Example. If the plane be 20 feet long, and the perpendicular height be 4 feet, then 500 lbs. would be balanced upon it by 100 lbs. because the plane is five times the length of the perpendicular height to which the weight is to be raised.

83. To the inclined plane may be reduced hatchets, chissels, and other edged tools, which are sloped only on one side.

OF THE WEDGE.

85. The wedge may be considered as two equally inclined planes united at their bases.

86. The advantage gained is in proportion as the length of the two sides of the wedge is greater than the back, or as the length of one side is greater than half the back.

Illustration. The wedge *a b c d x* may be divided into two inclined planes, *a v c z x*; and *b v d z x*, which may be used separately and will gain advantage as such, and therefore when united at *z x*, the advantage gained will be in the same proportion, as when they were used in different parts.

87. When the wood cleaves at a distance before the wedge, the advantage gained is in proportion as one side of the cleft is greater than half the length of the back.

88. The wedge is a very important mechanical power, used to split rocks, &c. which could not be effected by any of the other mechanical powers.

89. All instruments, as many sorts of chissels that are chamfered on both sides, are to be referred to the principle of the wedge.

OF THE SCREW.

90. The screw is never used without the application of a lever or winch to assist in turning it, and then it becomes a compound engine of very great force, either in pressing bodies closer together, or in raising great weights.

91. The screw may be conceived to be made, by cutting a piece of paper into the form of an inclined plane, and then wrapping it round a cylinder. The edge of the paper will form a spiralline round the cylinder, which will answerto the thread of the screw.

92. The advantage gained by this mechanical power, is in proportion as the circumference of the circle, made by the lever or winch

winch, is greater than the threads distance of the screw.

Illustration. It is evident that the winch or lever must turn the cylinder once round, before the weight, or the resistance can be moved from one spiral winding to another, as from *x* to *z*, see Plate III. fig. 22.

Example. If the distance of the spirals *z x* is half an inch, and the lever A three feet, or 36 inches long, then the circle described by the lever will be about 228 inches, or 456 half inches, consequently a force at the end of the lever, equal to only one pound, would balance a resistance of 456 pounds.

Corollary. Hence it appears, that the longer the winch or lever, and the nearer the spirals, the more advantage is gained.

93. A screw may be moved upward or downward in a fixed nut, as in fig. 22. or the nut may move on the screw, as in fig. 23.

94. Almost all kind of presses, common cork-screws, &c. act upon the principle of this mechanical power.

95. When a screw acts in a wheel, it is called an *endless* screw.

96. In the application of the mechanical powers, one third must be allowed to overcome the friction, and other obstacles, to which all machines are liable.

Example. If 60lbs. are required to balance any weight, with a mechanical power, 80 lbs. will be wanted to put the machine in motion.

97. In all machines, what is gained in power is lost in time.

Ex.

Example. If a man can raise by a single fixed pulley a beam, to the top of a house in two minutes, he will be able to raise six such beams in 12 minutes: but with a tackle, having three lower pullies, he will raise six beams with the same ease at once; but he will be six times as long about it, that is 12 minutes, because his hand will have six times as much space to pass over.

98. One capital advantage in the mechanical powers is, that if the six beams were in one piece, it might be raised by a tackle, though it would be impossible to move it by the unassisted strength of a single man.

99. Another advantage is, that by machines we can give a more convenient direction to the moving power, and apply its action at some distance from the body to be moved.

OF THE MOVING POWERS.

100. The principal moving powers are: first, the strength of animals, chiefly that of men and horses; secondly, the force of running waters and of wind; thirdly, the force of steam; fourthly, the force of springs; fifthly, the weight of heavy bodies.

101. The simple weight, as applied to clocks

clocks, jacks, and other machines, is the power which can be most easily applied as a first mover, and its action also is most uniform.

102. As this power requires to be renewed after a certain period, it is mostly used for slow movements.

103. The spring is a useful moving power, but, like the weight, it requires to be wound up after a certain time, whence it is also chiefly used for slow movements.

104. The spring differs from the weight in one remarkable respect, which is, that its action is never uniform, being strongest when most bent; but there are methods of rectifying this defect.

Example. Thus the spring of a watch is made to wind on a conical piece of metal, which assists the action of the spring when it is wanted.

105. The steam of boiling water is a most powerful agent, and recent improvements have extended the application of it from the smallest to the most powerful engines.

106. The force of running water, and that of wind, are very advantageous movers of many engines, such as pumps, mills, &c.

107. Running water is preferable to wind, as a mover of machines, on account of its uniformity.

108. As to the natural strength of living animals, it may be remarked, that a man of ordinary strength is reckoned capable of doing about one fifth part as much work as a horse.

OF PENDULUMS.

109. A pendulum is a heavy body hanging by a small string, wire, &c. which is moveable round a centre.

110. Each swing that a pendulum makes is called a *vibration* or *oscillation*.

111. All the vibrations of the same pendulum, whether great or small, are performed in equal times.

112. The longer a pendulum, the slower are its vibrations.

113. A pendulum that vibrates in this country in a second time, or, as it is said, that vibrates seconds, is a little more than thirty-nine inches long.

114. A pendulum that vibrates seconds at the equator must be somewhat shorter than at the poles.

115. A pendulum to vibrate half seconds will be only one-fourth part as long as one *that vibrates* seconds.

116. A pendulum to vibrate once in two seconds only, must be four times as long as that which vibrates seconds.

117. The lengths of pendulums are to one another as the squares of the number of vibrations.

Example. It is foundby experiment that a pendulum which vibrates 60 times in a minute is 39-13 inches nearly, therefore to find how long pendulums must be that vibrate 30, 50, and 120 times in a minute, we say, as

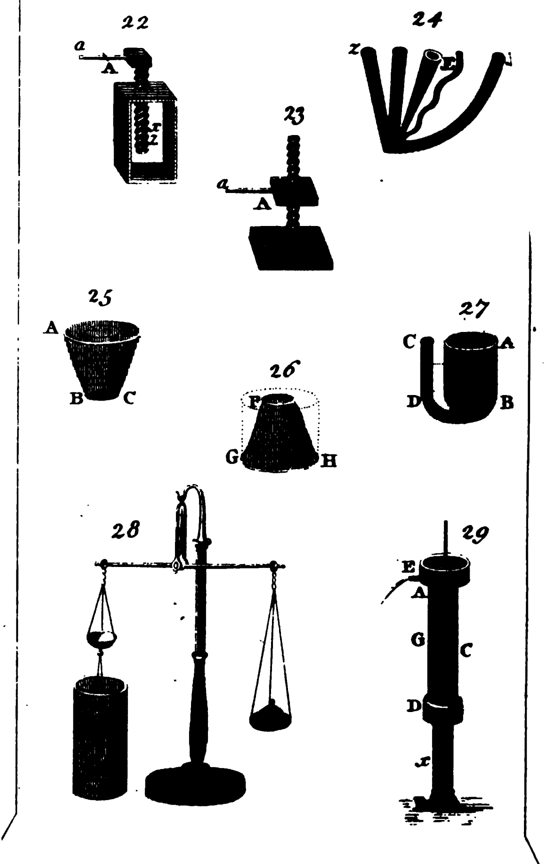
							inches.		*inches.*
30^2	:	60^2	::	39.13	:	156.52
50^2	:	60	::	39.13	:	56.34
120^2	:	60^2	::	39.13	:	9.78

118. As heat expands, and cold contracts all metals, a pendulum rod is longer in warm weather than in cold, which is a chief cause of irregularity in clocks.

HYDROSTATICS, OR THE LAWS OF FLUIDS.

119. A fluid is a body the parts of which yield to any impression, and are easily moved among each other.

120. Fluids are either non-elastic and in-*compressible,* as water, oil, mercury, &c. or elastic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elastic and compressible, as air, and the different gases.

121. The science of hydrostatics treats of the mechanical properties of non-elastic fluids, particularly of water.

122. Fluids are subject to the same laws of gravity with solids, but their want of cohesion occasions some peculiarities.

123. The parts of a solid are so connected as to form a whole, and their effort is concentrated in a single point called the centre of gravity: but the parts of a fluid gravitate independently of each other.

124. Fluids press not only like solids, perpendicularly, but also, upwards, sideways, and in every direction equally.

Experiment. Take a glass tube open at both ends, put a cork in one end, and immerse the other in water. The fluid will not rise far in the tube, but the moment the cork is taken out it will rise to a level with the surrounding water: which shews the pressure upwards.

125. A fluid kept in an open vessel will assume a flat surface parallel to the horizon, and will remain at rest.

Experiment. If a vessel, fig. 24. consist of pipes variously inclined, communicating with each other at B, and open at the top, water poured into any one of them will rise to the same level in all.

126. The pressure of the same fluid is in *proportion* to the perpendicular height, an

and is exerted in every direction, so that all the parts, at the same depth, press each other with equal force in every direction.

Experiment 1. If a bladder full of air be immersed in water, then the perpendicular pressure is manifest, for the deeper the bladder is immersed, the more will its bulk be contracted.

2. An empty bottle being corked, and by means of a weight, let down a certain depth into the sea, it will be broken, or the cork will be driven into it by the perpendicular pressure. But a bottle filled with water, wine, &c. may be let down to any depth, without damage, because in this case the internal pressure is equal to the external.

3. It is evident that the quantities of water in the different pipes, fig. 24. whatever be their size, press equally against each other, for if the water be suddenly taken out of the pipes *E*, *z*, or *F*, the surface of the water will instantly descend to a lower level in all the other pipes.

127. The horizontal bottom of a vessel sustains the pressure of a column of the fluid, the base of which is the bottom of the vessel, and the perpendicular height is equal to the depth of the fluid.

Experiment 1. In the vessel A B, fig. 25. the bottom C B does not sustain a pressure equal to the quantity of the whole fluid, but only of a column whose base is C B, and height C E.

2. In the vessel F. G, fig. 26, the bottom sustains a pressure equal to what it would be if the vessel were as wide at the top as bottom.

128. The pressure of a fluid upon any

give

given part of the bottom or sides of a vessel, is equal to the weight of a column of that fluid, having a base equal to that part of the bottom or side, and an altitude equal to the perpendicular height of the fluid above it.

Cor. Hence may be calculated the pressure upon, and the strength required for dams, cisterns, pipes,&c.

129. The hydrostatical paradox is this: that any quantity of fluid, however small, may be made to counterpoise any quantity, however large.

Experiment. If to the wide vessel A B, fig. 27. a tube C D be attached, and water be poured into either of them, it will stand at the same height in both; of course the small quantity in C D balances the large quantity in A B.

130. The upper pressure of fluids is shewn by the hydrostatical bellows.

Illustration. This machine consists of two oval boards, 16 inches in length, and about 14 in width, covered with leather, to rise and fall like the commou bellows, but without valves. A pipe three feet long is fixed in the top board. Let a little water run into he bellows to separate the boards, then weights to the mount of two or three hundred pounds may be put 1 the upper board; after which, if the pipe be supplied ith water, it will, by its upper pressure, sustain and t up the weights.

OF SPECIFIC GRAVITIES.

131. By the *specific gravities* of bodies, is meant the relative weights which equal bulks of different bodies have to each other.

132. It is usual to compare the weight of bodies with that of water, as it is by weighing them in water that their specific gravities are found.

133. A body immersed in a fluid will sink to the bottom, if it be heavier than its bulk of the fluid.

134. If it be suspended in it, it will lose as much of what it weighed in air, as its bulk of the fluid weighs.

135. All bodies of equal bulks, which would sink in fluids, lose equal weights when suspended therein; and unequal bodies lose in proportion to their bulks.

136. If the same body be successively placed in fluids of different specific gravities, it will displace different quantities of those fluids, in consequence of its sinking deeper in the lighter than in the heavier fluid.

137. If the weight of the body be equal to that of the same bulk of the fluid, then the body will remain at rest in any part of that fluid below the surface.

138. If a body heavier than an equal *bulk of a certain* fluid, be placed on the *surface of* that fluid, it will sink with the

excess of weight, by which the weight the body exceeds the weight of an eq bulk of the fluid.

141. The *hydrostatic balance*, used for fin ing the specific gravities of bodies, diffe but little from the common balance, see fig 28; only it has a hook at the bottom of on of the scales, on which different substance that are to be examined may be hung by horse-hairs, so as to be immersed in a vessel of water without wetting the scale.

If a body *x*, fig. 28, suspended under the scale, be first counterpoised in air by weights in the opposite scale, and then immersed in water, the equilibrium will be destroyed; then if a weight be put into the scale from which the body hangs to restore the equilibrium, that weight will be equal to the weight of water as large as the immersed body.

142. The specific gravities of all bodies that sink in water, may be found; first by weighing the body in air, then in water, and dividing the weight in air by the loss in water.

Example. A guinea weighs 129 grains in air, by being weighed in water it loses 7¼ grains, which shews hat a quantity of water of equal bulk with the guinea weighs 7¼ grains, divide 129 by 7¼, or 7-25, and the uotient will be 17.793, which proves the guinea to 17.793 times as heavy as its bulk of water.

143. The instrument used for comparing specific gravities of liquids, is called *the trometer*.

HYDRAULICS.

144. The science of Hydraulics teaches how to estimate the swiftness and force of fluids in motion.

145. Upon the principles of this science machines worked by water are constructed:—engines, mills, pumps, and fountains, are the result of the knowledge of hydraulics.

146. Fluids, by their pressure, may be conveyed over hills and valleys, in bended pipes, to any height not greater than the level of the spring from whence they flow.

147. Upon this principle fountains are formed: for if, near the bottom of any vessel, a small pipe bending upwards be fastened, the water will spout out through the pipe, and rise nearly as high as the surface of the water in the vessel.

148. The *common Pump,* improperly called the sucking-pump, consists of a pipe open at both ends, in which is a moveable piston that fits the bore exactly.

Illustration. Fig. 29 is the representation of a common pump: A D is called the barrel which contains the piston; B D the suction-pipe. At the junction of these two parts there is a fixed valve D opening upwards. The mode of operation is as follows: the part B is fixed in water, and the piston C is to be close down upon the valve D. In drawing up the piston from D to C a vacuum is formed in that part, consequently the air in the rest of the pipe will force its way through the valve D, and fill the part which had been exhaust-

exhausted, but it will be rarer than before, and not being equivalent to the pressure of the atmosphere upon the water in which the pump is immersed, the water will be forced up into the suction-pipe as far as *x*, until the air within be as dense as before. Upon depressing the piston a second time, the same effect is produced, till at length the water itself forces its way into the barrel. When the piston now descends, it is forced through the water, which cannot repass through D, it must therefore get above the piston by passing through its valve G, and when it is next raised. all the water above it will be lifted up, and will run off by the pipe E.

149. The *forcing Pump* consists of a barrel, a plunger, and two fixed valves, that should be air tight, and so disposed, as to let the water freely rise, but absolutely to hinder its return.

Illustration. In fig. 30, A B is the barrel, C a solid piston or forcer, at D is one valve opening upwards, the other is in the branching pipe S. When the forcer is first moved upwards in the barrel, the air below will be rarefied and the water rise up in B: by repeated strokes of the piston the water will be brought up between the fixed valves D and S. It cannot descend by D, but must make its way through the upper valve at S, which shuts the moment the water has passed. V is a strong air vessel closed at the top by a small pipe T that reaches nearly to the bottom. The water is forced along the rising pipe S, gets into the vessel, and rises above the lower part of the pipe T. The air which is above the water in the vessel being confined, and condensed into a smaller than its natural space, presses by its elasticity upon the surface of the water and forces it up the pipe T is a continued stream. This is *the principle* of the engine for extinguishing *fires.*

 150. Th

150. The water in a sucking-pump is raised from the well by the pressure of the atmosphere; and it can be raised only about 33 feet, because the weight of a column of the whole atmosphere is equal only to an equal column of water 33 feet high.

151. The forcing pump is unlimited in regard to the height to which it can raise water.

152. The air-vessel is added to the forcing pump, to give the water a more equable stream.

153. A constant stream may be produced by *two* barrels, with pistons moving up and down alternately.

PNEUMATICS.

154. The science of Pneumatics treats of the mechanical properties of elastic or aeriform fluids; such as their *weight*, *density*, *compressibility*, and *elasticity*.

155. The air in which we live surrounds the earth, and extends to a considerable height above it.

156. The air, together with the clouds and vapours that float in it, is called the atmosphere.

157. The air is not visible, because it is *perfectly* transparent.

Expe-

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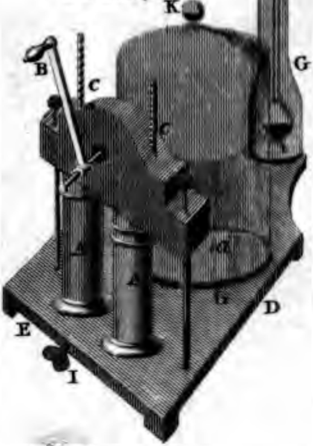
Air Pump



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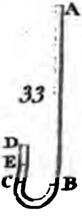

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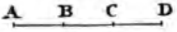


Experiment 1. The existence of the air may be ascertained by swinging the hand edgeways swiftly up and down, which gives the idea of separating the parts of some resisting medium.

2. Any swift motion, as of a stick, or whip, or that of a fan, proves the existence of air as a resisting medium.

158. The air being a heavy body, presses like other fluids, in every direction, upon whatever is immersed in it, and in proportion to the depths.

Example 1. It is known that the pressure of the atmosphere is less upon a high mountain, than in the plain or valley beneath.

2. The pressure of the air may be thus shewn: Cover a wine glass completely filled with water, or wine, with a piece of writing paper: then place the palm of the hand over the paper, so as to hold it tight and accurately even. The glass may then be turned upside down, and the hand removed, without the water running out. The pressure of the air upon the paper sustains the weight of water.

159. The air can be compressed into a much less space than it naturally occupies.

Experiment 1. Here is a glass tube open only at one end: it is of course full of air: I plunge the open end into a bowl of water, and you see the water rises an inch or so in the tube, the air therefore, which before filled the whole length of the tube, is compressed into a smaller space.

2. Here is a small cork swimming on a bason of water, I will cover it with an empty glass tumbler, which I force down through the water. The cork evidently shews, that the surface of the water within the tumbler is not on a level with the surface witho

This experiment proves that air is a body that prevents water from occupying the same space with itself: it proves also that the air is compressible, because the water does ascend to a small height in the glass.

160. The air is of an elastic, or springy nature, and the force of its spring is equal to its weight.

Experiment 1. This bladder is filled with air by blowing into it, and in this state it is highly elastic: it proves also that air is as much a substance as wood or metal, for no force can, without breaking the bladder, bring the sides together, though the parts of an empty bladder may be squeezed into any shape.

2. Open a pair of common bellows, in the usual manner, and then stop the nozzle securely, and no power can bring the parts together without first unstopping the nozzle or bursting the leather: another proof that the air is a solid substance.

161. When air is in motion, it constitutes *wind*, which is nothing more than a current of air, varying in its force, according to the velocity with which it flows.

162. Air-pumps are machines for exhausting the air from certain vessels adapted to the purpose.

Illustration. Fig. 31 represents one of the most convenient air-pumps. A A are two brass barrels, each containing a piston, with a valve opening upwards. The pistons are worked by means of the winch B, which moves them up and down alternately. On the *wooden* frame D E, there is a flat brass plate G, *ground perfectly flat*, and also a brass tube *communicating with the two* cylinders and the cock I, and opening

opening into the centre of the brass plate at *a*. K the glass receiver to be exhausted of air, is made to fit very accurately on the brass plate. Having shut the cock I, the pistons are worked up and down, and the air is suffered to escape, when the piston is forced down, because the valve opens upwards, but it is prevented from returning into the vessel for the same reason. The air is gradually exhausted from the receiver, which will become immoveably fixed. Upon opening the cock I, the air rushes violently and with a noise into the receiver.

163. Air is about 900 times lighter than water.

Example. A quart of air may be weighed in a Florence flask to which a little apparatus is added, and it is found to weigh 16 grains, but a quart of water weighs 14621 grains; the latter number being divided by the former gives 914, so that the air is 914 times lighter than water. The weight of the air is variable.

164. When the surface of a fluid, as water, quicksilver, &c. is exposed to the air, it is pressed by the atmosphere equally on every part, and is at rest.

165. If the pressure be removed from any part, the fluid, in that part, must yield and be forced out of its situation.

The following experiments shew what the pressure of the air amounts to:

Experiment 1. Into the receiver A, fig. 32, put a small vessel of quicksilver *x*, and through the collar of leather as at B, suspend a glass tube, closed at the upper end, over the quicksilver. The apparatus thus situated is to

be placed on the brass plate of the air pump, and the air completely exhausted from the receiver, the tube is then to be let down into the quicksilver, which will not rise in it as long as the receiver continues empty: but as soon as the air is readmitted, all the surface of the quicksilver is pressed upon by the air, except that portion which lies above the orifice of the tube: it will therefore rise in the tube, until the weight of the elevated quicksilver presses as forcibly on that part of it which lies beneath the tube, as the weight of the air does on every other equal portion without the tube.

2. Take a syringe or common water squirt, and having pushed the piston to the farthest end, immerse it in water, then draw up the piston and the water will follow: for when the piston is raised, the air is drawn out of the syringe, and the pressure of the atmosphere is removed from the part of the water immediately under it, consequently the water yields in that part to the pressure on the surface.

3. Upon this principle *sucking-pumps*, as they are called, act: the piston accurately fitting the inside of the barrel, by being raised, removes the pressure of the atmosphere from that part, and consequently the water is forced up by the pressure upon the surface.

166. The pressure of the atmosphere is capable of supporting about 33 feet of water or about 29 or 30 inches of quicksilver.

167. If a glass tube upward of thirty-one inches long be filled with quicksilver and have its aperture immersed in a bason of the same fluid, the altitude of the mercury in it will be found to vary both at different times and in different places.

168. Hence it appears that the weight of the

The atmosphere is variable, and the above mentioned tube filled with quicksilver has, from its shewing the actual weight of the atmosphere, been called *a barometer*.

169. The most usual altitude of the barometer, in London, is between 28 and 31 inches, but it is seldom to be seen below $28\frac{1}{2}$, or above $30\frac{1}{2}$ inches.

170. In calm weather when the air is inclined to rain, the mercury is commonly low. In serene settled weather the mercury is generally high. During very great winds, though unaccompanied with rain, the mercury sinks lowest of all with relation to the point of the compass from which the wind blows.

171. By removing the pressure from air it always expands, nor is it known to what degree this expansion will reach.

172. By increasing the pressure upon air it may be condensed into any given space however small, nor has this condensation any known limits. The density of the air is in proportion to the force that compresses it.

Experiment. This bent tube A B C D, fig. 33, is open at both ends. I have poured mercury in so as to rise in both sides of the tube to C and B; the part from C D is full of air at the common density: I stop up D so as to make it air tight, and pour mercury into A so that the column of mercury A B shall be equal in length

to the height at which it stands in the barometer at the time. The air in the shorter leg will now be compressed by the weight of the atmosphere, and also with an additional equal weight of a column of mercury. The mercury now in the shorter leg will be risen to E, and D E is only the half of D C: that is, the pressure of a double atmosphere compresses the air to half the space which it naturally occupies. If another column of mercury were added to the length A B, the air in D C would be reduced into one fourth the space that it formerly occupied.

173. As all the parts of the atmosphere press upon each other, the air near the surface of the earth is denser than that which is at some height above it.

174. The height to which the atmosphere extends has never been exactly ascertained; but at a greater height than 45 miles it will not refract the rays of light from the sun.

MISCELLANEOUS EXPERIMENTS.

Experiment 1. The resistance of air to falling bodies is shewn by exhausting a tall glass receiver of its air, and in that state the lightest body, as a feather, will fall to the bottom as soon as the heaviest metal.

2. If a cup of porous wood containing mercury be placed on the receiver of an air-pump, and the air from below be exhausted, the external pressure of the atmosphere will force the mercury through the wood in a sort of shower.

3. *Let the air* be taken from the pores of a piece *of dry wood, which* is then to be held under mercury

while

while the external air is admitted into the receiver, the mercury will be forced into all the pores, as may be seen by splitting the wood.

4. If two brass hemispheres of three or four inches in diameter, made for the purpose, be put together, and the external air exhausted, the pressure from without will require 150 lbs. to separate them : but if the external air be taken away they will separate of themselves.

5. This is a square phial with a small valve at top. I will put it under the glass receiver K of the air-pump, and exhaust the air out of the receiver, and the air will escape from the phial at the same time. The air now being suddenly admitted into the receiver, will dash the phial to pieces, because the valve prevents it from getting into the phial again.

6. The elasticity or spring of air is shewn by tying up a very small quantity of it in a bladder, and putting it under the receiver K : the receiver is now to be exhausted of air, and the little confined in the bladder will by its elasticity completely fill the bladder.

7. This square phial is full of air, and the cork accurately cemented in, so that no air can escape : I will put it under the receiver K and exhaust the air from the receiver ; the air within not being balanced by any without will burst the bottle in pieces.

8. Put a shrivelled apple under the receiver, and exhaust the air ; then the air within the apple will make it as plump and handsome as when it was first gathered ; but by the admission of the air it will return to its shrivelled state.

9. If a fresh egg with the small end cut off be put in a glass under the receiver, and the air taken away, the small bubble of air contained in the great end of the egg will expand, and force the contents of the egg from the shell.

10. Some beer made warm and put under the receiver, will appear to boil when the air is nearly exhausted from the glass.

11. The

11. The smoke of a candle will ascend in the air, but in an exhausted receiver it will fall to the bottom, which shews that it generally ascends because it is lighter than air.

12. The sound of a small bell may be heard while it is under a receiver full of air; but as soon as the air is exhausted, there will be no more sound.

Cor. Hence air is necessary to the propagation of sound.

13. Animals will not live, nor candles burn, for a single instant in an exhausted receiver.

14. A fig. 34, is a strong copper vessel, having a tube that screws into the neck of it, so as to be air-tight, and long enough as nearly to reach the bottom; *x* is the handle of a stop-cock. Having poured some water into the vessel, and screwed in the tube, the condensing syringe is to be adapted and the air condensed. The stop-cock is to be shut, while the syringe is unscrewed, then on opening the cock, the air by its great density acting upon the water in the vessel, will force it out into a jet of a considerable height. This is called the artificial fountain.

15. The sound of a bell is much louder in condensed than in common air.

16. A square phial that would bear the pressure of the common atmosphere, when the air is exhausted from the inside, will be broken by condensing the air around it.

OF ACOUSTICS.

175. Acoustics is the science which treats *of sound in general*; Diacoustics of refracted *sound, and* Catacoustics of reflected sound.

176. A sonorous body, whilst sounding, is unquestionably in a state of vibration, and the air, by similar vibrations, communicates and propagates these vibrations.

177. There are three principal causes of the variety of sounds: first, the greater or less frequency of the vibration of sonorous bodies; secondly, the quantity or force of the vibrating particles; and, thirdly, the greater or less simplicity of the sounds. Hence; are derived the height, strength, and quality of sounds.

178. The vibrations of a sounding body continue for a longer or shorter time, according as the body is more or less elastic or as it is thicker or thinner.

Example. When a string of uniform shape and quality is stretched between, and fixed to, two steady pins, as A, B, Fig. 35, if it be drawn out of its natural, or quiescent position A B, into the situation A B C, and if then it be let go, it will in consequence of its elasticity, not only come back to its position A B; but it will go beyond it, to the situation A D B, which is nearly as far from A B, as A C B was on the other side, and all this motion one way is called one vibration; after this, the string will go again nearly as far as C, making a second vibration; then nearly as far as D, making a third vibration, and so on; diminishing the extent of its vibrations gradually, until it settles in its original position A B.

179. The vibrations of a musical string are also communicated to other parts of it, which, at first sight, might be supposed to be at rest.

Example. If you divide a string as A D, fig. 36, into three equal parts, AB, BC, CD, by placing dots at C and B; place a bridge, like a violin bridge, at B, also place light bodies, such as small bits of paper, at C, and at other places of the string B D; then draw a violin bow over the part AB; you will find that all the bits of paper will be thrown off from the part BD, excepting the one at C; shewing that the point C remains at rest, whilst the remainder of the string is vibrating.

180. In general, sound travels through the atmospheric air at the rate of 1142 feet per second or one mile in less than five seconds.

181. The knowledge of the velocity of sound may be applied to the measurement of distances, when no better method can conveniently be used.

OPTICS.

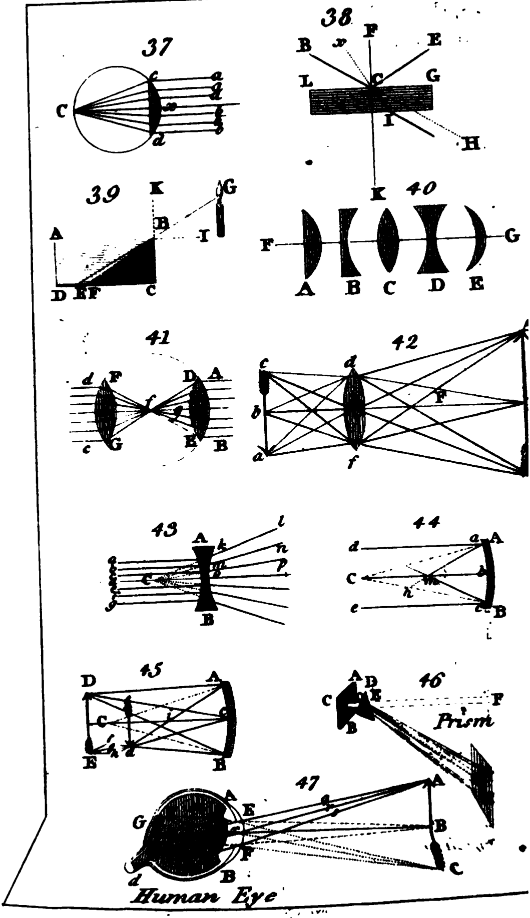
182. Light consists of an inconceivably great number of particles flowing from a luminous body in all manner of directions By a *ray* of light, is meant the motion of a single particle.

Example. The light of a candle, if there be nothing to obstruct the passage, will fill the whole space within a mile of the candle every way, with luminous particles, before it has lost the least sensible part of its substance.

183. Light travels from the sun to the

earth

Optics.



earth in about eight minutes, that is at the rate of nearly two hundred thousand miles in a second of time.

184. The particles of light must be incomprehensibly small, for its rays cross each other in all possible directions without the least disturbance.

Experiment 1. Take a piece of brown paper and make a pin-hole in it, through this small aperture, a great variety of objects may be seen, as trees, houses, &c. The light proceeding from all these objects, must pass at the same instant through the hole, and cross each other before they reach the eye, yet the clearness of vision is not disturbed by it.

2. Make a pin-hole in a piece of black paper, and hold it in an upright position before a row of candles; then on the wall, which must be at a little distance from the paper, some of the rays which flow from all the candles through the hole in the paper will form as many specks of light on the wall as there are candles, each speck being as clear and distinct, as if there was only a single speck from one candle.

185. The particles flowing from a luminous body, as the sun, or a candle, and falling upon our eyes give us the idea of light.

186. The rays of light falling on bodies, and reflected to our eyes, give us the idea of those bodies.

Experiment. Go into a dark room and you have not the smallest conception of the several articles of furniture that it contains: admit the rays of light, these at the same instant (owing to the great swiftness with which they travel) fall upon the bodies in the room and

and are reflected to the eyes, thereby exciting in our minds the idea of these bodies.

187. Every point of a visible body reflects the rays of light in all manner of directions.

Cor. Hence every part of the surface of a body which is towards a spectator will be visible to him, when no intervening object stops the passage of light.

188. The rays of light move always in straight lines.

Ex. No object can be seen through the bore of a bended pipe.

189. A parcel of rays of light proceeding from a point is called a *pencil of rays*.

190. A medium is any transparent body which suffers the rays of light to pass through it. Thus water, air, and glass are *media*.

19 Parallel rays are such as move always at the same distance from each other.

192. If rays continually recede from each other, as from C to *c d* (fig. 37) they are said to *diverge*.

193. If they continually approach each other, as in moving from *c d* to C they are said to *converge*.

194. The point at which converging rays meet is called the *focus*.

195. The point towards which they tend, but which they are prevented from reaching by some obstacle, is called the *imaginary focus*.

194. While

196. While the rays of light continue in any medium of an uniform density, they are straight.

197. If rays of light, pass from one medium to another in a *perpendicular* direction, they proceed through this medium in the same direction as before.

Ex. If F C. fig. 38, be a ray of light passing from air into water, it will continue on to K.

OF REFRACTION.

198. When rays of light pass *obliquely* out of one medium into another, which is either more dense, or more rare, they are bent out of their former course, and they are then said to be *refracted.*

199. Rays of light are always refracted *towards* a perpendicular in a *denser* medium and this refraction is more or less, in proportion as the rays of light fall more or less obliquely on the refracting surface.

Experiment. Let B C (fig. 38) be supposed to be a ray of light passing out of air into water or glass L G, at the point C; F C is a line drawn perpendicular to L G, and the ray B C instead of proceeding along C H, will be bent towards the perpendicular C, as along C I.

200. When light passes out of a denser into

into a *rarer* medium, it moves in a direction *farther from* the perpendicular.

Experiment 1. Thus if the ray C I (fig. 38) pass out of glass into air, it will not proceed in C x, but in the direction C B, farther from FC than C x.

2. Take a pan A B D C (fig. 39,) with an upright side into a dark room; let in, by means of a small hole in the window-shutter, a ray of light C B, so as to fall upon the bottom of the pan at E; mark the spot E; then, without moving the pan, fill it with water, and the ray will now not pass on to E, but will be refracted to F. The candle G will answer as well as the direct rays of the sun.

3. If a shilling be stuck on the part F with wax, so that an eye at C cannot see it when the pan is empty, it will become visible the moment the vessel is filled with water.

4. Take a glass goblet half full of water and put a shilling into it, then put a saucer or plate upon it, and holding it tight on, turn plate and glass together; a byestander unacquainted with the laws of refraction, will suppose that he sees a shilling and a half crown; the one is seen by refraction through the water, the other by the rays after refraction at the surface.

201. A *lens* is a glass ground into such a form as to collect or disperse the rays of light which pass through it.

202. There are various kinds of lenses, named according to their forms.

203. A *plano-convex* lens has one side flat, and the other convex, as A, fig. 40.

204. A *plano-concave* is flat on one side, and convex on the other, as B.

205. A double convex is convex on both *sides as C.*

206. A

206. A *double concave* is concave on both sides, as D.

207. A *meniscus* is convex on one side and concave on the other, as E.

208. The *axis* of a lens is a line passing through the centre: thus F G is the axis to all the five lenses.

209. If parallel rays fall upon a plano-convex lens, they will be so refracted as to unite in a point behind, called the principal focus, or focus of parallel rays.

Example. Thus the rays *a*, *b* (fig. 37,) falling upon *c d*, are refracted towards the perpendicular C *x*, and unite in C.

210. The distance from the middle of the glass to the focus, is called the *focal distance*.

211. The focal distance of a plano-convex lens, is equal to the diameter of the sphere of which the lens is a portion.

212. The focal distance of a double convex lens is equal to the radius of a sphere of which the lens is a portion; see fig. 41

213. All the rays of the sun which pass through a convex glass, are collected in its focus.

214. The force of the heat at the focus is to the common heat of the sun, as the area of the glass is to the area of the focus.

Illustration. If a lens four inches in diameter collect the sun's rays into a focus at the distance of 12 inches, the

the image will not be more than one tenth of an inch in diameter, the surface of this little circle is 1600 times less than the surface of the lens, and consequently the heat will be 1600 times greater at the focus than at the lens.

Cor. 1. Hence the construction of common burning glasses, which are all double convex lenses.

Cor. 2. Hence the reason why furniture has been set on fire by leaving a globular decanter of water incautiously exposed to the rays of the sun; which acts as a double convex lens.

215. If another double convex F G fig. 41, be placed in the rays at the same distance from the focus, it will so refract the rays, that they shall go out of it parallel to one another.

Illustration. It is evident that all the rays, except the middle one, cross each other in the focus *f*, of course the ray D A, which is uppermost in going in, is the lowest in going out as G *c*.

216. If a candle be placed at *f*, the diverging rays between F G, will, upon going out of the lens, become parallel at *d c*.

217. If the candle be placed nearer the the glass than the focus, the rays will *diverge* after going through the lens.

218. If the candle be placed farther from the glass than the focus, the rays will *converge*, after passing through the glass, and meet in a point, which will be more or less distant from the glass, as the candle is nearer to, or farther from its focus.

219. Where the rays meet they will form an inverted image of the flame of the candle.

Experiment 1. The inverted image of the candle may by means of a common burning glass be taken on a sheet of paper which is to be placed at the meeting of the rays.

2. If an object A B C, (fig. 42) be placed beyond the focus F of the convex glass *d e f*, some of the rays which flow from every point of the object on the side next the glass, will fall upon it, and after passing through it they will be converged into as many points on the opposite side of the glass, where the image of the whole will be formed, which will be inverted. Thus the rays flowing from A, as A *d*, A *e*, A *f*, will converge in the space *d a f*, and by meeting in *a* will there form the image of the point A : and so of those rays flowing from B and C, and of course of all the intermediate parts.

3. If the object A B C be brought nearer the glass, the picture *a b c* will be removed to a greater distance from it.

220. The picture will be as much larger or less than the object, as its distance from the glass is greater or less than the distance of the object.

221. When parallel rays pass through a double concave lens, they will diverge after passing through the glass, as if they had come from a point in the centre of the concavity of the glass. This point is called the *imaginary focus*.

Example. If the rays *a b c*,&c. (fig. 43,) pass through AB, and C be the centre of concavity, then the ray *a*, af-

ter

ter passing through the glass, will go on in the direction *k l*, as if it had come from C and no glass in the way; the ray *b* will go on in the direction *m n*, and so on.

222. When parallel rays pass through a plano-concave lens, they diverge after passing through it, as if they had come from a point at the distance of a whole diameter of the glassy concavity.

OF REFLECTION.

223. When rays of light strike against a surface, and are sent back from it, they are said to be *reflected*.

224. The ray that comes from any luminous body, and falls upon a reflecting surface, is called the *incident ray*.

Example. If L G, (fig. 38,) be a reflecting surface, as a looking glass, then B C is the incident ray, and C E is the *reflected* ray.

225. The *angle of incidence* is that which is contained between the incident ray, and a perpendicular to the reflecting surface in the point of reflection.

226. The *angle of reflection* is that contained between the perpendicular and the *reflected ray*.

227. The *angle of refraction* is that contained between the refracted ray and the perpendicular.

Illustration. In fig. 38, B C being the incident ray, B C F is the angle of incidence, F C E is the angle of reflection, and I C K is the angle of refraction.

228. A *mirror* or *speculum* is an opaque body whose surface is finely polished, so that it will reflect the rays of light which fall upon it, and thus represent the images of objects.

229. Mirrors are made of metal, or glass, polished on one side and silvered on the other.

230. There are three kinds of mirrors, viz. the *plane*, the *convex*, and the *concave*.

231. Common looking-glasses are called plane-mirrors; but the concave and convex are denominated mirrors.

232. When a ray of light is reflected from any surface, the angle of reflection is equal to the angle of incidence.

Ex. Thus the angle B C F (fig. 38) is equal to F C E. The same is true of convex and concave mirrors.*

* Let the lines C *a* and C *c*, (fig. 44,) be drawn, which are perpendicular to the concave surface *a c*, and it will be found that the angle of incidence d *a* C is *equal to the angle of reflection* C *a m*, and *e c* C is *equal to* C *c m*.

233. When parallel rays fall upon a concave mirror, they will be reflected, and meet in a point, at half the distance of the surface of the mirror from the centre of its concavity.

Ex. If the parallel rays (fig. 44) *d a*, C *m b*, and *e c*, fall upon the concave mirror A B, then *d a* will be reflected along *a m*, C *b* will be reflected along *b m*, and *e c* along *c m*; of course they all meet in *m*; and *m b* is found to be equal to *m* C, or half C *b*.

234. The rays of light that proceed from any celestial object may be esteemed parallel at the earth, therefore the image of that object will be found half way between the mirror and its centre of concavity.

235. The rays which proceed from any remote terrestrial object, will be converged at a little greater distance than half way between the mirror and the centre of concavity, and the image will be inverted with respect to the object. See fig. 45.

236. When the object is more remote than the centre of concavity, the image is less than the object, and is between the object and the mirror.

237. When the object is nearer than the centre of concavity, the image will be more remote and larger than the object.

238. If the object be in the centre of the mirror's concavity, the image and object will be equal and coincide.

Ex-

48

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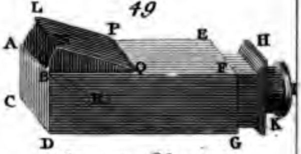
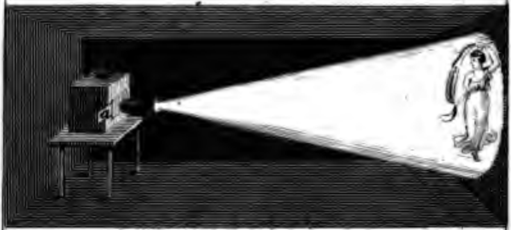


Camera Obscura

50



Magic Lanthorn

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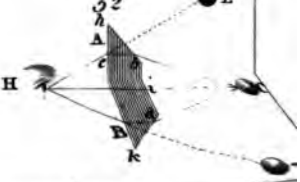

Experiment. If I stand before a large concave mirror, beyond its centre of concavity, I shall see an inverted image of myself in the air. And if I hold out my hand towards the mirror, the hand of the image will come out and coincide with it, as if the two were shaking hands. If I reach my hand farther, the hand of the image will pass by it, and if I move my hand to one side, the hand of the image will move to the other. A by-stander will see nothing of the image, because none of the reflected rays can enter his eyes.

OF THE DIFFERENT REFRANGIBILITY OF THE RAYS OF LIGHT.

239. Light is not a simple homogeneous body, but compounded of seven different species, each of which, in passing from one medium to another, suffers a different degree of refrangibility.

240. To examine the different colours of a ray of light, a small hole must be made in the shutter of a dark room, and the ray must fall upon a prism in an oblique direction.

Illustration. Let A B (fig. 46) represent part of the shutter of the window of a room, in which no light enters, excepting through the hole C. If the light of the sun be received upon a screen at any distance from the hole, as at *E*, a circular luminous spot will be formed upon the screen, which is larger in diameter than the hole at C. Place a glass prism D O F before the hole, so that the light may pass through in the

direction perpendicular to the axis of the prism; and instead of going straight from E to F, the light which comes through the hole will, by passing through the prism, be bent and dispersed in such a manner as to form a coloured spectrum or image G H upon a screen, which may be situated at any distance from the prism, but below the straight direction C F. The spectrum G H is about five times as long as its breadth, and is terminated by semi-circular ends. The highest part G is of a beautiful *red* colour, which, by insensible shades, degenerates into an *orange*, then a *yellow*, a *green*, a *blue*, an *indigo*, and a *violet*, which is the colour next to H, viz. at the lowest part of the spectrum.

241. If the whole spectrum be divided into 360 parts, the *red* will occupy 45 of them, the *orange* 27, the *yellow* 48, the *green* and the *blue* 60 each, the *indigo* 40, and the *violet* 80.

242. By mixing the seven primitive colours in these proportions, a dusky white is obtained.

Ex. Paint on a circular board the seven colours in their proper proportions, and then whirl the board with great velocity; it will appear of a dirtiesh white. If the colours were more perfect and accurately defined, the white would be more perfect also.

243. The seven colours are reducible to three, viz, the red, the blue, and the yellow.

244. The most remarkable instance of the separation of the primary colours of light is that of the rainbow.

239. The

245. The rainbow is formed by the reflection and refraction of the rays of the sun's light from the drops of falling rain.

246. The colours of the rainbow are frequently visible among the waves of the sea, the tops of which are blown by the wind into small drops: they are sometimes seen on the ground, when the sun shines on a thick dew.

247. Cascades and fountains frequently exhibit the appearance of rainbows, and water blown violently from the mouth of an observer, whose back is turned to the sun will produce the same phenomenon.

OF THE EYE AND VISION.

248. The eye is of a globular form, and is composed of three *coats*, covering one another, and inclosing different substances called *humours*.

249. The three coats are the *sclerotica*, the *choroides*, and the *retina*.

250. The three humours are the *aqueous*, the *crystalline*, and the *vitreous*.

Illustration. A B G, fig. 47, is a section of the globe of the eye, the three circles represent the three coats: the outer one is the sclerotica, but the part A *E F B* is called the *cornea*. The middle circle is the cho-

choroides, the fore part of which is called the *iris*, and the inner circle represents the *retina*, which serves to receive the images or objects produced by the refraction of the different humours of the eye. The aqueous humour fills up all the space A, E, F, B, *x*; *y z*, is the crystalline in the form of a double convex lens; and the vitreous humour occupies all the interior part of the eye *m n* behind the crystalline. From the hinder part of the eye proceeds the optic nerve *d*, which conveys to the brain the sensations produced on the retina.

251. Objects are seen by means of their images being painted on the retina of the eye.

Illustration. As the object A, B, C. sends out rays that fall on the *cornea* of the eye between E, and F, and by passing on through the pupil and humours, they will be converged to as many points on the *retina*, and will there form a distinct inverted picture *c b a*, of the object. Thus the pencil of rays *q r s*, that flow from A will be converged to the point *a* on the retina; those from B, will be converged to the point *b*; those from C to point *c*; and so of all the intermediate points; by which means the whole picture *a b c* is formed and the object is made visible.

252. Though the images of objects are painted on the retina in an inverted state, yet they are seen erect.

253. Dimness of sight generally attends old people, which may arise either (1) by the eyes growing flat, and not uniting the rays at the retina: or (2) by the humours losing their transparency in some degree, which makes every object appear faint and indistinct.

254. Spectacles are intended to assist the sight of those whose eyes are either too round or too flat.

255. *Concave* glasses are necessary to those whose eyes are too round.

Illustration. When the eye is too round the rays proceeding from objects are converged to a focus before they get to the retina; to remedy this a concave glass is used, because the property of this is, to *disperse* the rays which prevents them from coming to a focus so soon as they otherwise would.

256. Convex glasses are necessary to those whose eyes are too *flat.*

Illustration. When the eye is too flat the rays proceeding from objects do not converge to a focus so soon as they reach the retina, a convex glass has the property of converging the rays and of course of bringing them to a focus sooner than they otherwise would.

257. Eyes that have their humours of a due convexity cannot see an object distinctly at a less distance than about seven inches.

258. There are numberless objects too small to be seen at that distance.

OF OPTICAL INSTRUMENTS.

259. Microscopes are instruments for viewing small objects.

260. They apparently magnify objects because they enable us to see them nearer, without affecting the distinctness of vision.

Ex. Take a piece of brown paper and make a pin hole in it, then bring the eye close to the hole, and the paper within two or three inches of a small print, which will be apparently much magnified, though without the paper the letters would at that distance be wholly illegible.

261. There are three kinds of microscope, the *single*, the *compound* and the *solar*.

262. The single microscope, is only a small double convex lens, having the object placed in the focus, and the eye at the same distance on the other side.

263. The magnifying power of the single microscope is found by dividing seven inches, the least distance at which an object can be seen distinctly by the naked eye, by the focal distance of the lens.

Illustration. By the experiment just mentioned the brown paper was brought twice or three times nearer the book than the distance of distinct vision and the length of the letters were magnified two or three times. With a lens whose focal distance is only one inch, the *length of an object* would appear to be seven times *larger than it is*, and the surface would be magnified *49 times, that is the* square of 7.

Ex.

Ex. If the focal distance of the lens be only the ¼ of an inch, then the diameter of an object will be magnified 28 times (because 7 divided by ¼ is the same as multiplying 7 by 4) and the surface will be magnified 784 times.

264. The compound microscope consists of an object-glass and an eye-glass.

Illustration. The object to be viewed is *a b*, fig. 48, *c d*, is the object-glass, and *e f*, the eye-glass. The object is placed a little beyond the focus of *d c*, the rays will converge and the image be formed at *g h*. The image, therefore, and not the object, is viewed by the eye D E, through the lens *e f*, which is so placed that the image *g h* may be in its focus, and the eye about the same distance on the other side; the rays of each pencil will be parallel after going out of the eye-glass as at *e* and *f*, till they come to the eye at *k*, where they will begin to converge by the refractive humour of the eye, and having crossed each other and passed through the crystalline and vitreous humours, they will form the inverted image A B on the retina.

265. The magnifying power of the compound microscope is in proportion as the image is larger than the object, and also according as we are able to view it at a less distance.

Ex. If the image *g h* is 4 times larger than the object *a b*, and by the help of the eye-glass we can view it 7 times nearer than we could by the naked eye, on both these accounts the diameter of the object will be magnified 4 times 7, or 28 times; and the surface 784 times.

266. There are generally two eye-glasses

by which means the object is less magnified, but more of it is seen.

267. The solar microscope depends on the sun-shine, and is used in a darkened room

268. It is composed of a tube, a looking-glass, a convex lens, and a single microscope.

269. The sun's rays are reflected by the *looking-glass* through the tube upon the object, the image of which is thrown upon a white skreen, sheet, &c. placed at a distance to receive it.

270. The magnifying power of the instrument is in proportion as the distance of the image from the object glass is greaer than the object itself is from it.

Ex. If the distance of the object from the object-glass be ¼ of an inch. and the distance of the picture be 10 feet or 120 inches then the object is magnified in length 480 times.

271. Telescopes are used for viewing objects at a great distance; of these, there are two kinds, the *refracting* and the *reflecting*.

272. The common refracting telescope consists of an object-glass which is nearest the object, and an eye-glass next the eye.

273. This telescope inverts the image with respect to the object and makes it unfit for viewing terrestrial objects.

274. The

274. The magnifying power of this telescope is as the focal distance of the object-glass is to the focal distance of the eye-glass. Therefore if the former be divided by the latter the quotient will express its magnifying power.

Ex: An object-glass of 10 feet or 120 inches focal distance, will admit of an eye-glass whose focal distance is 2½ inch, and 120 divided by 2½ or in decimals by 2, 5 will give 48, the number of times that such a telescope will magnify the diameter of an object.

275. A telescope to shew objects in their natural posture has three eye-glasses. The two aditional lenses is to give the erect position of objects, see fig. 41.

276. The three eye glasses have all their focal distances equal, and the magnifying power is found as before, by dividing the focal distance of the object-glass by the focal distance of one of the eye-glasses.

277. The *camera obscura* is made by fixing a convex glass in a hole of a window shutter, and if no light enters the room but through the glass the pictures of all objects on the outside may be seen in an inverted position, on a white paper placed in the focus of the lens.

278. If the convex lens be placed in a tube in the inside of a box, within which is a looking glass sloping backwards we get a portable camera obscura.

Illus-

Illustration. Fig. 49 represents a box consisting of two parts. The outer A C B D E F G has a shutter or cover L N, which moves round an hinge P Q, and when open, as in the figure, it carries two lateral boards, which serve to exclude the external light as much as possible from the rough glass O, upon which the observer is to look. The fore side of the box is wanting, and in that aperture another narrower box E H I K G slides. This box wants the inner side, and has a convex glass lens fixed at I. If this machine be turned with the lens I towards any objects that are well illuminated, an inverted picture of them will be formed within the box on the side A B C D, and that picture may be rendered distinct by moving the sliding box E H G K in or out, in order to adjust the focus according to the distance of the objects. At the back part of the box a flat piece of looking-glass is situated at an inclination of half a right-angle, as is shewn by the dotted lines B R; in consequence of which the rays of light fall upon the looking-glass, and are reflected upwards to the rough glass O. The picture then is formed upon that rough glass, and will appear erect to a spectator situated behind the box, and looking down upon the glass O, from which a drawing may be made.

279. The *magic lanthorn* is an instrument used to magnify paintings on glass, and throwing their images upon a white screen in a darkened chamber.

Illustration. Fig. 50 represents the machine with the effect it produces. Fig. 51 shews the internal parts of the machine placed at their proportionate distances. The lantern contains a candle A, a reflector M N, which is so situated as to have the light A *in its focus*. On the fore part of the lantern there is a *thick double convex* lens C D, or a plano-convex (*usually called* a *bull's* eye) of short focus. The lantern

tern is closed on every side, so that no light can come out of it, but what passes through the lens C D. In the direction of this lens there is a tube x, fig. 50, fixed to the lantern, which has a lateral aperture from side to side; through this the glass slider *a a* with the painted small images, is moved in an inverted position. G H, fig. 51, represents one of these images. The forepart of the tube x contains another sliding tube, which carries the double convex lens E F. The effect of those parts is as follows: The thick lens C D throws a great deal of light from the candle A upon the image G H. And to increase that light still more the reflector M N is often, but not always, placed in such lanterns; for as the flame is in the focus of the reflector, the light proceeds in parallel lines from the reflector to the lens C D. The image G H being thus well illuminated, sends forth rays from every point which, by passing through the lens E F, are converged to a focus upon the wall and form the large images as is shewn in fig. 50. In some magic lanterns, instead of the single lens E F, two lenses are used of less curvature, and set at a little distance from each other; which act rather better than a single lens.

280. The multiplying glass is made by grinding down the side of a convex glass into several flat surfaces.

Illustration. Fig. 52 is the representation of a multiplying glass with three flat sides *h i k*. The object C seen by the eye at H will appear multiplied into as many different objects as the glass contains plane surfaces. For since rays flow from the object C to all parts of the glass, and each plane surface will refract these rays to the eye, the same object will appear to the eye in the direction of the rays, which enter it through each surface. Thus the rays falling *in the direction* C *i* H will shew the object in its true place

place at C, because there they suffer no refraction; but the rays falling upon the surfaces *h b* and *d k*, will be refracted to *e* and B, and therefore to an eye at H, the object C will appear in the directions H *e* E and H B D as well as in that of H *i* C. The same thing will happen if instead of three there be any number of flat surfaces.

ASTRONOMY.

281. Astronomy is the science which explains the forms, numbers, distances, motions, and appearances of the stars, or celestial bodies.

282. The celestial bodies are the Sun, the planets with their moons, the comets and the fixed stars.

283. The Earth which appears to us like a vast plane, is, in reality, a round, or convex surface.

Illustration. That the Earth is spherical is proved (1) From its casting a round shadow upon the Moon during an eclipse (2) From its having been sailed round by several persons. (3) From our seeing farther the higher we stand (4) From our seeing the masts of ships on the sea while the hull is hidden by the convexity of the water.

284. The sensible horizon is that apparent circle which on an extensive plane seems to circumscribe our sphere of vision.

285. The

284. The rational horizon divides the heavens into two equal parts or hemispheres; the visible which is above, and the invisible which is below it.

285. The Sun, the Moon, the planets, and most of the stars, appear to go continually round the earth from east to west, and to perform each revolution in about 24 hours.

286. The meridian divides the time of the course of the celestial bodies above the horizon into two equal parts; hence, when the Sun is at the meridian, it is mid-day.

287. On turning our back towards the north, we have the south exactly before us, the east in the left, the west on the right, the zenith over our heads, the nadir under our feet.

288. The equator, or equinoctial, is that great circle which divides the globe into equal parts.

289. The same circles, planes, &c. are supposed to exist in the heavens, as well as upon the earth; so that the south and north poles of the earth are said to be situated precisely under those of the heavens.

290. The whole sphere appears to perform its revolution regularly in the space of 23 hours 56 minutes and 4 seconds.

291. The Sun rises and sets every day at different points of the horizon, and crosses

the meridian every day at a different point; but never goes farther from the equator than about 23°, 28′, either towards the north or towards the south of it.

292. The ecliptic is the Sun's apparent annual path; the angle which it forms with the equator is called the obliquity of the ecliptic, and the points where it intersects the equator are called the equinoctial points.

293. The zodiac is a broad portion of the heavens, following the direction of the ecliptic, and extending about 8 degrees on each side of it, so as to include the latitude of the planets.

294. As the Sun appears every day in a different point of the ecliptic, it thence seems to revolve in a circle parallel to the equator, but receding from it first about 23° 28′ towards the north, then approaching the equator and again receding from it about 23° 28′ towards the south, and so on.

295. The tropics are the circles parallel to the equator which the Sun seems to describe when at its greatest distance from the equator; that towards the north being called the tropic of Cancer, and that towards the south the tropic of Capricorn.

OF

OF THE SOLAR SYSTEM.

296. The solar system consists of eleven primary planets, eighteen secondary planets or moons, and a number of comets.

297. The names of the primary planets are Mercury, Venus, the Earth, Mars, Ceres, Pallas, Juno, Vesta, Jupiter, Saturn, and Herschel.

298. The Earth has one moon, Jupiter four, Saturn seven, and Herschel six. The other seven planets do not appear to have any moons.

Illustration. The sun S. (Pl. vii. fig. 53) is the centre of the system ; nearest to the Sun revolves Mercury ☿, then Venus ♀, the Earth ⊕, Mars ♂, Ceres, Pallas, Juno, Vesta,* Jupiter ♃, Saturn ♄, and Herschel ♅.

299. All the planets move round the Sun from west to east, and in the same direction do the moons move round their primaries, excepting those of the Herschel, which move from east to west.

300. The paths in which the planets move are called their orbits.

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* The Ceres, Pallas, Juno, and Vesta, have all been discovered within the last seven years: and, at present, have no characters appropriated to them; they are very small bodies, and called by Dr. Herschel *asteroids.*

301. The orbits of the planets, though circular in the figure, are in nature eliptical.

302. The planets perform their revolutions in different periods of time: the time of performing their revolution is called their year.

303. The planets turn on their axes, and the time employed for this purpose is called their day. *See opposite page* †.

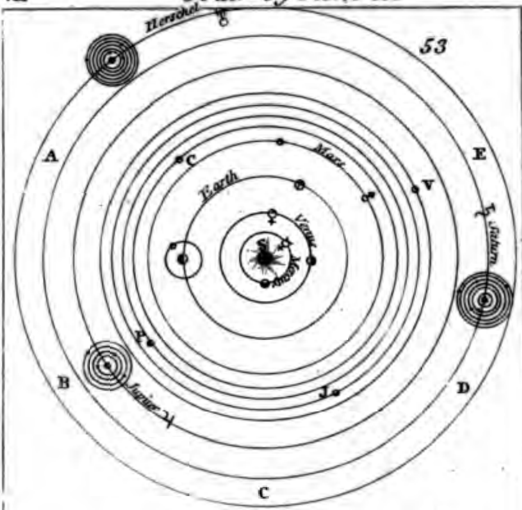
304. The planets are opaque bodies, and shine only by reflecting the light which they receive from the Sun.

Illustration. Mercury and Venus, when viewed by a telescope, seem often to be only partly illuminated, and have the appearance of our moon when she is horned, having the illuminated part always turned to the sun. From the appearance of the boundary of light and shadow upon their surfaces, it is concluded that they are spherical, a circumstance which is confirmed by most of them having been found to turn on their axes.

305. Venus and Mercury being nearer the Sun than the earth, are called *inferior* planets; and all the others, which are without the earth's orbit, are called *superior* planets.

Solar System &c

53



Electricity

54

55

56

† The following Table will give the Diameters of the Sun and Planets; the mean distances of the Planets from the Sun; and the time occupied in their diurnal and annual revolutions.

	Diameters in English miles.	Distances from the Sun.	Diurnal rotations round their own axes.	Time of revolving round the Sun.
The Sun	813,246	———	25 d. 14 h. 8 m.	———
Mercury	3,224	37,000,000	unknown.	84 d. nearly.
Venus	7,867	68,000,000	23 h. 21 m.	225 d. nearly.
The Earth	7,930	95,000,000	24 h.	365 d. 6 h. 9 m.
Mars	4,189	144,000,090	24 h. 39 m. 22 s.	687 d. nearly.
Ceres	160	260,000,000	unknown.	unknown
Pallas	80	260,000,000	unknown.	1703 d. 16 h. 48m.
Juno*	—	300,000,000		2012 d.
Vesta				
Jupiter	89,170	490,000,000	10 h. nearly.	4332 d. 14 h. 27m.
Saturn	79,042	900,000,000	10 h. 16 m.	10759 d. 1 h. 51 m.
Herschel	35,112	1,800,000,000	unknown.	30737 d. 18 h.

* The distances, magnitudes, &c. of Juno and Vesta have not yet been ascertained.

Illustration. It is certain that Mercury and Venus go round the Sun, because they are sometimes seen passing between the Earth and Sun, and sometimes they go behind the sun.

2. Their orbits are within that of the Earth's, because they are never seen in *opposition* to the Sun; that is, they never appear to rise from the horizon when the Sun is setting.

3. The orbits of all the other planets are known to surround that of the Earth, for they are sometimes seen in opposition to the Sun, and they never appear to be horned, but always nearly or quite full.

306. When a planet is situated so as to be between the Sun and the Earth, or so that the Sun is between the Earth and planet, then the planet is said to be in *conjunction* with the Sun.

307. When the Earth is between the Sun and any planet, then that planet is said to be in *opposition*.

308. The inferior planets, have two conjunctions with the Sun, but the superior have only one, because they can never come between the Earth and Sun.

309. When a planet comes directly between the Earth and Sun it appears to pass over the sun's surface, and this is called the transit of the planet.

310. The planets move faster when they are nearest the Sun, and slower in the remotest part of their orbits.

311. The

311. The *Sun* is a spherical body of immense magnitude, being about a million of times larger than the Earth.

31 . When viewed through a telescope, several dark spots are seen adhering to its surface. From these spots it is found that the Sun turns on its axis in about 25 days.

313. By Dr. Herschel and others it is thought that the Sun is a most magnificent and habitable globe.

314. MERCURY is the planet nearest to the Sun, and on that account is very seldom visible. It shews phases like the moon, and never appears to us quite full.

315. VENUS is the brightest, and, to appearance, the largest of all the planets.

316. Venus is generally called the morning or evening star, according as it precedes, or follows the apparent course of the sun.

317. Venus and Mercury occasionally pass over the Sun's surface. These are called the transits of Venus or Mercury.

318. By the transit of Venus the Sun's distance from the Earth was first accurately ascertained.

319. The EARTH is not a perfect sphere, but a spheroid, having the diameter at the equator between 30 and 40 miles longer *than that* at the poles.

320. The Earth being of a globular form, people stand upon opposite sides of it, and these are called *antipodes* to each other.

321. The Earth has a *diurnal* motion about its axis, and an annual one about the Sun.

322. The diurnal motion of the Earth is the cause of day and night.

Illustration. When one half of the Earth is turned towards the Sun, it receives his rays, and is illuminated, causing day; and when this half is turned from the sun, we are in darkness, and then we have night.

323. TWILIGHT is owing to the refraction of the rays of light by our atmosphere, through which they pass, and which, by bending them, occasions some to arrive at a part of the earth, that could not receive any direct rays from the sun.

324. The axis of the Earth, in its journey round the Sun, is inclined to the plane or level of its orbit.

325. This inclination of the Earth's axis, in its annual motion round the Sun, occasions the diversity of the seasons.

Illustration. The lengthening and shortening of the days and the different seasons are produced by the motion of the earth T. pl. ix. in its orbit round the sun S. The axis of the earth N. S. inclines to the plane of the orbit, and is parallel to itself in all parts of its orbit. In June the North pole N. inclines to the sun, and it is summer to the northern parts of the earth, in December the North pole declines from the sun, and the

the northern parts have more darkness than light, and then to them the days are short, and it is winter. In March and September the axis of the earth is perpendicular to the centre of the sun, and the poles of the earth N. S. are in the boundary of light and darkness, and the days and nights are equal all over the earth.

326. The MOON, next to the Sun, is the most remarkable object in the heavens. It is a spherical body, like the Earth, round which it revolves, and by the influence of which it is carried round the Sun.

327. The average distance of the Moon from the Earth is 240,000 miles.

328. The Moon turns on her axis in the same time as she performs her revolution round the Earth, viz. in about $29\frac{1}{2}$ days.

Cor. Thence the moon has always the same side towards the earth.

329. The moon's year is of the same length as that of the Earth, but the number of their days is very different. To the earth there are $365\frac{1}{4}$ days in a year: to the Moon only about 12^1.

330. The moon, at its *conjunction*, is invisible, its first appearance afterwards is called *new* moon.

331. At its *opposition* its whole disk is enlightened, it is then called *full* moon.

Illustration Pl. x. S is the sun, T the earth, ABC, &c. the moon in its orbit. One half of the moon is *always* enlightened by the sun. At A, the moon is between

between the earth and sun, and is invisible as represented at *a*: at B. the enlightened part *x*, *z*. is turned to the earth, and she appears horned as at *b*: at C the half of the enlightened side is turned to the earth, and she appears a half moon as at *c*: at D the part *x z*. is turned to the earth, and it appears as at *d*, and at E the whole of the enlightened part of the moon is turned to the earth, and we have full moon as at *e*. As she passes through the rest of the orbit, he puts on the same phases as before, but in a contrary order.

332. The Earth is a satellite to the moon, and subject to the same changes as that body undergoes.

333. The Earth appears more than 13 times larger than the moon appears to us. At new moon to us the Earth appears full to her.

334. The Moon is seen by means of the light from the Sun, which is reflected to us.

335. Its changes depend upon its situation relatively to the Earth and Sun.

336. MARS is not so bright as Venus or Jupiter; his colour is of a dusky red hue.

337. CERES is a very small planet, situated next to Mars; it was discovered on the first day of the present century by M. Piazzi, an Italian astronomer.

338. PALLAS is another very small planet, discovered by Dr. Olbers of Bremen, on the 28th of March, 1802.

339. JUNO was discovered by M. Harding, on the first of September, 1804.

340. VESTA was first seen by Dr. Olbers on the 29th of March, 1807; it has been

seen

seen also by Mr. Groombridge, Mr. Lee, and other astronomers in this country.

341. JUPITER is the brightest planet next to Venus: when seen by a telescope, several belts are observed around its surface, parallel to its equator.

342. Jupiter is attended by four moons, which are frequently eclipsed by the shadow of the planet falling upon them.

343. The eclipses of Jupiter's satellites have been very useful in determining the longitudes of places, and the velocity of light.

344. SATURN can scarcely be seen by the naked eye. It is surrounded by a flat and broad ring that reflects the light.

345. Saturn has seven satellites of different sizes, and its body is surrounded also by belts, like those of Jupiter.

346. The HERSCHEL planet can rarely be seen but by means of a telescope. It is attended by six satellites.

347. COMETS, like the planets, revolve about the Sun.

348. They move in excentric ellipses, and the periods of their revolution are so long, that only three are known with any degree of certainty.

349. Comets are only visible to us when they are in that part of their orbit which is nearest to the Sun, and then they move so fast as soon to become invisible to us.

350. When they approach the Sun, they often exhibit the appearance of a beard or tail, that reflects the light very brilliantly.

OF THE FIXED STARS.

351. The Fixed Stars are so called because they do not change their places with regard to one another as the planets do.

352. They are commonly classed into seven magnitudes; the largest are called stars of the first magnitude, and the smallest those of the seventh.

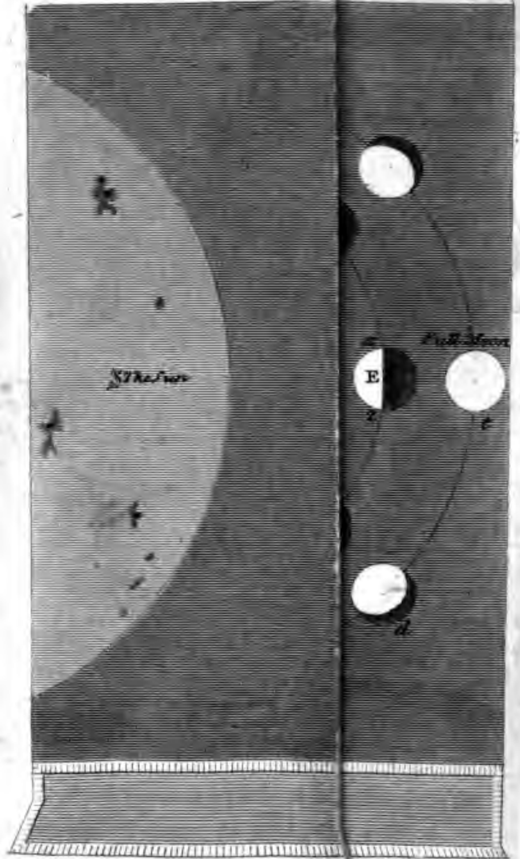
353. Although the number of stars appear to us as innumerable, this is a deception occasioned probably by the refraction and reflection of the rays of light passing from them through our atmosphere.

354. There are seldom more than a thousand stars visible at any one time.

355. The stars are divided into groups or constellations, called by the names of animals and other objects which they are supposed to resemble, such as the Great Bear, the Eagle, Swan, &c.

356. The fixed stars, from their immense distance, must shine by their own light, and *are probably* Suns like our Sun, to different *systems of* planets.

X



357. Many of the fixed stars, which to the eye appear as single stars, are found to consist of two.

358. There are also clusters of stars called *nebulæ*, the most remarkable of these is that broad zone called the Milky Way.

359. According to Dr. Herschel, each nebula is composed of a prodigious number of suns, and each sun is destined to give light to a system of worlds that revolve about it.

OF ECLIPSES.

360. When any heavenly body is obscured or darkened by the shadow of another falling upon it, or by the interposition of any body, it is said to be eclipsed.

361. The eclipses of the Sun and Moon are the most striking, and were formerly regarded as ominous of impending evil.

362. As the Earth is an opaque body, enlightened by the Sun, it will cast a shadow towards that side which is farthest from the Sun.

363. The Moon revolves about the Earth near enough to pass through the shadow of the earth.

364. An eclipse of the moon takes place whe

when the Sun, the Earth, and the Moon are in, or very nearly in, a straight line.

365. An eclipse of the Moon can take place only at the time of full moon.

366. On account of the inclination of the Moon's orbit to that of the Earth, an eclipse cannot take place every full moon.

367. When the Moon passes entirely through the Earth's shadow, the eclipse is *total*: when only a part of it passes through the shadow, the eclipse is *partial*.

368. An eclipse of the Sun is occasioned by the Moon's coming directly between the Earth and the Sun, and thereby obstructing our view of the Sun.

369. When the Moon happens to be between the Sun and Earth at the time of new moon, there will be an eclipse of the Sun.

370. As the Moon is so much smaller than the Earth, only a small part of the earth's surface can, at the same time, experience an eclipse of the Sun.

371. When any one of the heavenly bodies disappears by another body coming before it, it is called an *occultation*.

372. The *occultations* and approximations of the fixed stars by the Moon are of use in determining the *longitudes* of places.

OF THE TIDES.

373. The ebbing and flowing of the sea is owing to the attraction of the Sun and Moon, but chiefly to that of the Moon.

374. This attraction cannot alter the shape of the solid parts of the Earth, but it has a great effect on the water, and causes it to assume a spheroidal figure, the longest axis being in the direction of the Moon.

375. It is the highest tide at the place which is perpendicularly under the Moon, or where the Moon crosses the meridian.

376. The tide is at its greatest height, not when the Moon is on the meridian but some time afterwards, because the force by which the Moon raises the tide continues to act for some time after it has passed the meridian.

377. The oval figure of the waters keeps pace with the Moon in its monthly journey round the Earth.

378. The Earth, by its daily rotation upon its axis presents each part of its surface to the action of the Moon.

379. There are two tides in every place, in

 about

about 25 hours, because the action of the moon produces a tide in the place over which it passes, and also in the opposite surface of the globe at the same time.

380. When the action of the Sun and Moon conspire together, as at full and new moon, the tides are highest, and are *called spring* tides.

381. When they counteract each other, as in the quarters, they produce the lowest or *neap* tides.

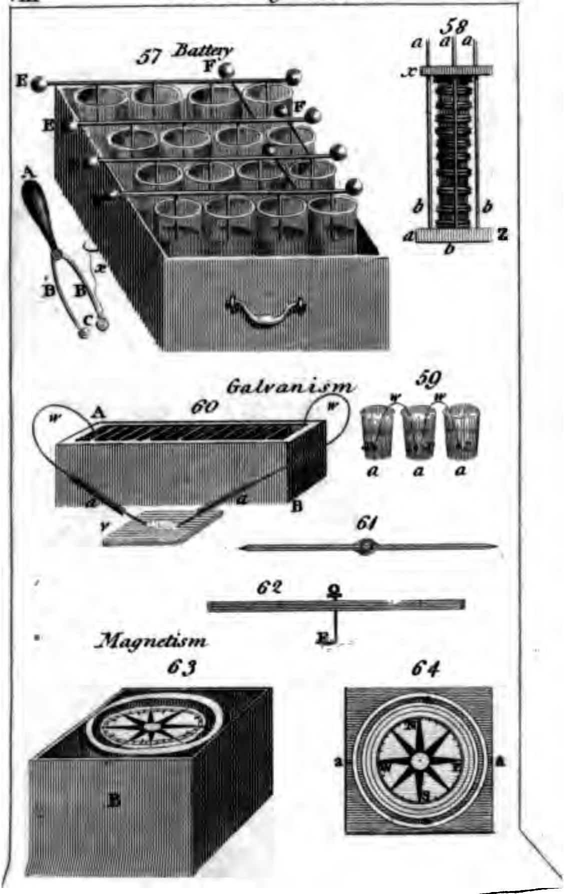
ELECTRICITY.

382. The Earth and all the bodies with which we are acquainted are supposed to contain a certain quantity of an exceedingly subtle fluid, called the electric fluid.

383 The certain quantity belonging to all bodies is called their natural share, and produces no sensible effects.

384. When any body becomes possessed of more or less than its natural quantity, it is said to be electrified, and is capable of exhibiting certain appearances which are ascribed to the power of electricity.

Ex. 1. Take a stick of sealing wax and rub it with *your hand, or with* a piece of flannel, or on your coat sleeve,


57 Battery
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Galvanism
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Magnetism
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sleeve, and it will have the power of attracting small bits of paper or other very light substances when held near them.

2. If a clean and dry glass tube be rubbed several times upwards and downwards, and then presented to any small light substance, it will immediately attract and repel them alternately for a considerable time. The tube is then said to be *excited.*

3. If a glass tube be rubbed several times in the dark and then brought within about half an inch of the finger, a lucid spark will be seen between the finger and the tube, accompanied with a snapping noise, and the finger at the same time will perceive the sensation of a prick from a pin. The attraction, repulsion, sparkling and noise, are the effects of electricity, and are denominated electrical appearances.

4. If an oblong piece of metal, such as a poker, be suspended by means of a dry silk string, and the excited glass tube be presented to its upper end, then the lower end of the metallic body will exhibit the same phenomena as the tube itself, which shews that the electric fluid passes through the metal.

5. If, instead of the metallic body, a stick of glass or sealing wax be suspended, none of these phenomena will be exhibited, which shews that the electric fluid does not pass through these substances.

385. All those bodies which, like the metallic substance, transmit electricity, are called conductors of that fluid.

386. Those substances that will not transmit the electric fluid are called *electrics,* or *non-conductors.*¶

387. The metals, semi-metals, and metallic ores, are conductors of electricity; so also are charcoal, water and other fluids, except

excepting the aerial fluids and oil. Almost all saline and many earthy substances are likewise conductors.

388. The following substances are electrics or non-conductors of electricity: viz. vitrified substances, precious stones, amber, sulphur, resinous substances, wax, silk, cotton, feathers, wool, hair, paper, elastic fluids, sugar, oils, metallic oxides,* animal and vegetable ashes, dry vegetable substances, as baked wood, &c.

389. All substances become conductors when they are made hot.

390. When a body has more than its natural quantity of this fluid it is said to be *positively* electrified: when it has less than its natural share, it is said to be *negatively* electrified.

391. When a conductor is so surrounded by non-conductors that the electric fluid cannot pass from it to the earth, it is said to be *insulated*.

Experiment. The human body is a good conductor of electricity, but if a person stand on a cake of rosin or on a stool supported by glass legs, the electric fluid cannot pass from him to the earth.

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* *The explanation and illustration of this and some other terms must be referred to an easy Grammar of Chemistry,* which I shall speedily publish.

392. The principal method of exciting the electric fluid is friction.

393. When a conductor and an electric are rubbed against each other the electricity is the most powerfully excited: in this case the electric fluid passes from the conductor to the electric.

Experiment 1. If I rub a smooth glass tube with my hand, the electric fluid will leave the hand, and pass upon the tube, which will now have more than its natural quantity.

2. If the finger or any conducting substance, be presented to the tube, the electricity will pass into it.

394. Two substances both positively or both negatively electrified, *repel* each other.

395 Two substances, of which one is positively and the other negatively electrified, attract each other.

396. If the person who rubs a glass tube be insulated, both the person and the glass tube become electrified, and capable of attracting and repelling light bodies; but the electricity of the person will differ from that of the tube, as the following experiment will shew.

Experiment 1. Let two cork balls, connected by a linen thread, be held by a silk thread, attached to the middle of the former, at some distance from a wall; then bring the excited tube near the balls, and

it will first attract, and soon after repel them; this repulsion will continue for a considerable time though the tube be removed.

2. Let another pair of cork balls be brought in contact with the insulated person, and they also will repel each other.

3. But if the two pairs of balls be brought near, they will attract each other, and the electrical virtue will disappear; which shews that there are two electricities, one being the reverse of the other, and seeming to have what the other wants.

4. If the insulated person rub a stick of sulphur, or resin, or sealing wax, that substance will acquire the electricity which in the preceding experiment was acquired by the insulated man.

Cor. Hence positive, and negative electricity have been called *vitreous* and *resinous*.

397. These electricities always accompany each other, for if any substance acquires the one, the body with which it is rubbed acquires the other.

398. When one side of a conductor receives the electric fluid, its whole substance is instantly pervaded with it; whereas when an electric is presented to an electrified body, it becomes electrified in a small spot only.

399. If to one side of an electric, viz. a pane of window glass, you communicate positive electricity, the opposite side will be negatively electrified, and that plate is said to be charged.

400. The positive and negative electricities cannot come together, unless a commu-

nication

nication by means of conductors is made between their sides.

401. When the two electricities are united, their virtues are destroyed, and the act of their union is called the electric shock.

402. Machines have been contrived for rubbing together electrics and conductors, and for collecting the electric fluid from surrounding bodies. These are called electrical machines.

Illustration. Fig. 54, represents an electrical machine of the simplest sort. G E F is a strong board, which supports all the parts of this machine, and which may be fastened to a table by means of one or more iron or brass clamps, as Q: the glass cylinder A B is supported by the two glass legs, G and E. I R, is the rubber, and I R K, is a silken flap. This cushion or rubber is fastened to a spring which proceeds from a socket cemented on the top of the glass pillar S. The lower part of this pillar is fixed into a small board which slides upon the bottom board of the machine, and by means of a screw nut and a slit at H, may be fixed more or less forward, in order that the rubber may press more or less upon the cylinder, N F is a glass pillar which is fixed in the bottom board, and supports the prime conductor M L of hollow brass or tin plates, which has the collector, or pointed wires at L, and a knobbed wire at M. From the brass knob O a longer spark may be drawn than from any other part of the conductor. When the cylinder is turned swiftly, the friction of the glass against the rubber causes the electric fluid which was in the rubber to pass to the glass, from whence it

it is conveyed to the prime conductor, the points of which *a* are presented to every part of the cylinder in succession. If a chain be put on the knob *x*, the other end of which hangs on the ground there will be a constant supply of the electric fluid to the prime conductor, which, if other bodies are presented to it, will keep discharging all the while in sparks. The rubber is supplied by means of the things in immediate contact, and these again are supplied by the general mass of the fluid that is lodged in the earth.

OF ELECTRICAL ATTRACTION AND REPULSION.

403. Bodies, that are charged with the same electricity repel each other; but if one have more and the other less than its share, they will attract one another.

Experiment 1. If a tuft of feathers be hung on the prime conductor L M, fig. 54. the moment they are electrified by turning the wheel of the machine, they will endeavour to avoid one another and stand erect: because being all electrified by the same electricity, they repel each other.

2. A large feather, will, if placed in the hole *z*, when the machine is worked, become beautifully turgid, expanding its fibres in all directions; and they collapse when the electricity is taken off by presenting any conducting substance to them.

3. *Excite* a glass tube 18 or 20 inches long, then *present to it* a small feather, which will first be attracted by it, and afterwards jump from it. If no other

other body happen to be in the way it will tend towards the ground; but if the tube be held under it, it will be still repelled, and may be driven about for a considerable time.

4. Suspend a plate of metal from the conductor, and underneath it at the distance of about three or four inches put another plate of the same size; upon the lower one small feathers, pieces of paper, &c. may be placed, these will, as soon as the machine is worked, jump to the plate, from which they will be repelled, and fly to discharge themselves upon the lower plate, after which they will be attracted and repelled again.

5. If two balls made of cork or of the pith of elder about the size of large peas be fastened to silk threads, they will hang parallel to each other, and be in contact; but when brought near the electrified prime conductor, they will strongly repel each other.

6. These balls in their electrified state shew whether the electricity is positive or negative; for if it be positive, by applying an excited stick of sealing wax the thread will collapse; but if it be negative, the sealing wax will make them recede still further.

404. A pair of cork or pith balls is used to discover the presence of electricity, and is denominated an electrometer.

Ex. *Fig*. 55, represents a *quadrant* electrometer, which may be fixed in the hole z of the prime conductor, fig 54. It consists of a very light rod; and pith ball A turning on the centre of a semicircle B. According to the strength of the electricity the pith balls flies off, and the scale marks the degree in which the prime conductor is electrified.

405. If a body containing only its natural share of electricity be brought near a body that is electrified, positively or negatively

tively, a part of the electricity in the form of a spark will force itself through the air, from the latter to the former.

406. When two bodies, one electrified positively the other negatively, approach each other, the superabundant electricity rushes violently from one to the other, to restore the equilibrium.

407. If an animal be placed so as to form part of this circuit, the electricity in passing through it produces a sudden and violent effect called the *electric shock*.

408. The motion of electricity in passing from a positive to a negative body is so rapid that it appears to be *instantaneous*.

409. When any part of one side of glass is presented to a body electrified positively or negatively, that side of the glass becomes possessed of the *contrary* kind of electricity to the side of the body it is presented to, and the other side of the glass is possessed of the same kind of electricity as the other body.

Experiment. If the knob O of the prime conductor, fig. 54, be electrified positively, and a pane of glass be presented to the side next to O, it will be negatively electrified, and the other side will be positively electrified.

410. Electricity communicated to glass *does not spread* beyond the spot where it is thrown,

thrown, on account of its non-conducting quality.

411. Electricity may be communicated to the whole surface of glass or any part of it, if it be covered with a metallic substance as tin-foil. This is called *coating* the glass.

412. If a conducting communication be made between both sides of a glass thus *coated* and *charged* with electricity, a discharge takes place.

413. Glass of any form, provided it be sound, will answer the purpose, but cylindrical jars are chiefly used.

414. A glass bottle or jar properly coated for electrical purposes is called a *Leyden* phial, or jar, from the place where this property was discovered.

Illustration. Fig. 56. represents a Leyden jar coated with tinfoil on the inside and outside within about three inches of the top of its cylindrical part; and having a wire with a round brass knob, or ball A, at its extremity. This wire passes through the cork or wooden stopple D; at its lower extremity is a piece of chain that touches the inside coating in several parts. To charge this jar, a communication is made between the electrical machine and the brass knob A, while the outside of the jar communicates with the earth by the table or the hand.

Experiment 1. Bring the knob A of the jar near the prime conductor, and after a few turns of the machine the jar will be charged: that is the inside of the jar will be positively and the outside negatively electrified: or if the inside is negatively, the outside will be pos-

positively electrified. R is a discharging rod which is used to convey the superabundant electricity from one side to the other where there is less than the natural share. The discharging rod consists of two brass knobs *a a* attached to wires, which move round a joint *x* fixed to a glass handle R.

2. When one of the knobs is applied to the ball A, and the other to the outside coating, a communication is made between the outside and the inside of the jar, by which the equilibrium is instantly restored by the superabundant electricity passing from one side to the other, appearing in the form of a vivid flash, accompanied with a loud report.

3. A shock may be taken by putting one hand to the outside coating, as at *a*, and bringing the other to the knob A.

4. Any number of persons may receive the shock together by laying hold of each other's hands, the person at one end touching the outside of the jar, and the person at the other end bringing his hand near the knob A. If there were a hundred persons so situated they would every one feel the shock at the same instant. The electric fluid may be conveyed many miles in a moment of time.

415. Several Leyden jars, connected together by making a communication between all the outsides, and another communication between all their insides, form an electric battery.

Illustration. Pl.viii. fig.57. represents a battery consisting of 16 jars, coated with tinfoil, and disposed in a proper box. The wires, which proceed from the inside of every four of those jars, are screwed or fastened to a common horizontal wire E, which is knobbed at each

each extremity, and by means of the wires F, F, F, the inside coatings of 4, 8, or 12, or of all the 16 jars may be connected. The inside of the box which contains these jars, is lined with tinfoil. On one side of this box there is a hole, through which a strong wire or hook passes, which communicates with the lining of the box, and of course with the outside coatings of the jar. To this hook a wire is occasionally fastened, which connects it with one branch of the discharging rod, B B C A.

416. Electricity, by means of the battery, is capable of producing the most powerful effects.

Ex. 1. A very slender wire, as *x*, being made part of the circuit, will by the discharge of the battery instantly become red-hot. It sometimes melts into small globules of different sizes.

2. If between two slips of window glass some gold leaf be placed and the slips of glass be pressed firmly together, and the shock from a battery be sent through them, the gold leaf will be forced into the pores of the glass.

3. If the gold leaf be put between cards, and a strong charge be passed through them, it will be completely fused.

4 Gunpowder may be fired by the electrical battery.

417. Metallic points attract the electricity from bodies silently, which renders them useful in defending buildings from *lightning*

418. When electricity enters a point it appears in the form of a star: when it goes out from a point, it puts on the appearance of a brush.

 419.

419. Instruments may be put in motion by the electric fluid which issues from a point: hence we have electrical orreries, mills, &c.

420. *Lightning* is the rapid motion of vast masses of the electric matter.

421. *Thunder* is the noise produced by the motion of lightning.

422. When the electric fluid passes through highly rarefied air, it constitutes the *aurora borealis* or *northern lights*.

423. Most of the great convulsions of nature, such as earthquakes, whirlwinds, hurricanes, &c. are generally accompanied with and dependent upon electrical phenomena.

GALVANISM.

424. The science of Galvanism appears to be another mode of exciting electricity: it derives its name from Galvani who first discovered it.

425. Electricity properly so called is chiefly excited by friction; but the effects of Galvanism are produced by the chemical action of bodies upon each other.

426. The nerves and muscles of animals are most easily affected by the Galvanic fluid.

427.

427. In 1791, Galvani of Bologna discovered that a dead frog may have its muscles brought into action by very small quantities of electricity.

428. He also discovered that the same motions may be produced in the dead animal merely by making a communication between the nerves and muscles by means of conducting substances.

Ex. 1. If a living frog, or a live fish, as a flounder, having a slip of tinfoil pasted upon its back, be placed upon a piece of zinc, whenever a communication is formed between the zinc and tinfoil the spasms of the muscles are excited.

2. If a person place a piece of one metal as a half-crown above, and a piece of some other metal as zinc below his tongue, by bringing the outer edges of these pieces in contact, he will perceive a peculiar taste.

3. If a person in a dark place put a slip of tinfoil upon the bulb of one of his eyes, and a piece of silver in his mouth, by causing these pieces to communicate, a faint flash of light will appear before his eyes.

429. The conductors of the Galvanic fluid are divided into the *perfect* and *imperfect*.

430. The perfect conductors consist of metallic substances and charcoal.

431. The imperfect conductors are water and oxydating fluids, as the acids, and all the substances that contain these fluids.

432. The simplest galvanic combinations must consist of three different conductors, not wholly of one class. When two of the

three

three bodies are of the first class, the combination is said to be of the first order; otherwise, it is said to be of the second.

433. It seems to be indispensibly requisite that in simple galvanic circles, the conductors of one class should have some chemical action upon those of the other.

Ex. If a piece of zinc be laid on a piece of copper, and a piece of card or flannel moistened with a solution of salt in water, and then three other layers in the same order, and so repeated several times, the whole will form a pile or battery of the *first* order.

434. When the three bodies which form a galvanic circle of the first order are laid upon one another, the upper and under one not touching, then these two extremes are in opposite electric states.

435. The galvanic effects may be increased to any degree by a repetition of the same simple galvanic combination.

436. These repeated combinations are called galvanic piles or batteries, which may be constructed of various forms.

Ex. 1. Take a number, say 12, of plates of silver, and the same number of pieces of zinc, and also of woollen cloth, the last are to be soaked in a solution of sal-ammoniac in water: with these a pile is to be formed, as in fig. 58. viz. a piece of silver, a piece of zinc, a piece of cloth, and thus repeated. These are to be *supported with* three rods of glass *a b*, and pieces of *wood x and z*, and the pile is complete, and will afford

ford a constant current of electric fluid, through any conducting substance: thus if one hand be applied to the lower plate and the other to the upper one, a shock will be felt, which is repeated as often as the contact is renewed.

The plates will soon become *oxydated*, and require cleaning in order to make them act.

2. Another battery consists of a row of glasses of any shape, as *a a*, fig. 59. containing a solution of salt and water, into each of these except the two on the outside is put a plate of zinc *z*, and another silver *x*; these plates communicate by means of the wires *w w*, and so fastened that the silver *x* in one glass is connected with the zinc *z* in the other; when one hand is dipped into the first glass, and another in the last, a shock is felt. The glasses may be of any number.

3. The most convenient kind of battery consists of a trough A B made of baked wood, three inches broad and about as deep; in the sides of the trough are grooves opposite to each other: into each pair of grooves is fixed by cement a plate of zinc and silver soldered together, and in the order of silver and zinc, silver and zinc, the cement must be filled in so as to prevent any communication between the different cells. The cells are to be filled with a solution of water and sal-ammoniac: when a communication is made between the first and last cell, by means of the hands, a strong shock is felt. The shock is felt as often as the contact is renewed.

4. Several persons, by joining hands, having first wetted them with water, may receive the shock.

437. The spark from a powerful galvanic battery acts upon and inflames gunpowder, charcoal, cotton, and other inflammable bodies.

Ex. 1. Fill the battery (Fig. 60.) with water and nitrous acid, in the proportion of 9 parts of water and one of acid, and wipe the edges of the plates very dry, then the wires *w w* are to be fastened to pieces of copper and put into the outer cells: *a a* are little glass tubes to hold the wires by. Bring the ends of the wires together on the plate of glass *v*, and a spark will be perceived: if gunpowder be laid on the glass between the points of the wires it will be inflamed.

2. Gold and silver leaf may be inflamed in this way: Dutch gold burns with a beautiful green light; silver with pale blue; gold with yellow light.

488. By galvanism many facts are explained in common life which were unintelligible before.

Ex. 1. Porter is said to have a peculiar taste when drank out of a pewter vessel; here is a complete galvanic circle, of the second order; the moisture of the under lip is one conductor of the second class, the porter is the other, and the pewter is the conductor of the first class.

2. Another Galvanic circle is seen by the discoloration of a silver spoon in eating eggs; the saliva and fluid egg are conductors of the second class, and the silver of the first.

3. Pure mercury retains its splendor a long time, but let it be amalgamated with tin, and it is quickly oxydated.

4. Works in metal, the parts of which are soldered together, soon tarnish in the places where the metals are joined.

5. The nails and the copper in the sheathing of ships are soon corroded about the place of contact. These are the effects of Galvanism.

MAGNETISM.

439. Magnetism explains the properties of the loadstone or natural magnet, which is a dark coloured and hard mineral body, and is found to be an ore of iron.

440. The magnetic properties may be communicated to other feruginous bodies, which are thence called artificial magnets. These properties, however, act upon no other substance but iron.

441. Natural and artificial magnets, as well as the bodies upon which they act, are either iron in its pure state, or such compounds as contain it.

442. All magnets attract iron.

443. When a magnet is at liberty to move itself freely, it constantly turns the same part towards the north pole and the opposite part towards the south pole of the earth.

444. Those parts of the magnet's surface which it turns towards the poles of the earth are called the north and south poles of the magnet.

445. The property of pointing to these poles is called its directive power ; and when it places itself in that direction, it is said to traverse.

446. The magnetic meridian is a plane perpendicular to the horizon, and passing throug

through the poles of the magnet when standing in their natural direction.

447. The declination of the magnet or of the magnetic needle, is the angle which the magnetic meridian makes with the meridian of the place where the magnet stands.

448. The north or south poles of two magnets repel each other; but the north pole of one attracts the south pole of another.

449. The inclination or dipping of the magnetic needle expresses the property which the magnet possesses of inclining one of its poles towards the horizon, and elevating the other pole above it.

450. Any magnet may, by proper methods, be made to impart its properties to iron or steel.

451. When a piece of iron is brought within a certain distance of one of the poles of a magnet, it is attracted by it; the attraction is strongest at the poles.

452. The magnetic attraction is not in the least diminished by the interposition of any bodies except iron.

453. Soft iron is attracted by the magnet, more forcibly than steel, but is not capable of preserving the magnetic property so long.

454. Heat weakens the magnetic power, nd a great heat destroys it.

455. The addition of weight to a magnet kept

kept in its proper situation, increases the magnetic power.

456. The north pole of a magnet is more powerful in the northern, and the south in the southern parts of the world.

457. When a magnet with two poles is freely suspended or floats upon water with no iron near it, it places itself in the magnetic meridian, and it is this principle that makes it so useful to seamen.

458. When a magnet is kept freely suspended, so that it may turn north and south, the pilot, by looking at its position, can steer his course in any given direction.

459. An artificial magnet fitted up in a proper box is called the *magnetic needle*, and the whole together, is called the *mariner's compass*. See fig. 61—64.

460. Though the north pole of the magnet always points toward the northern, and the south towards the southern parts, yet that direction is seldom in the exact direction of the poles of the earth, that is, the magnetic and the real meridian seldom coincide, and the angle which they make is called the angle of the declination of the magnetic needle.

461. This declination is said to be *east* or *west* according as the north pole of the needle is eastward or westward of the true meridian of the place.

462.

462. At present the declination o
magnetic needle is about 24 degrees
ward.

463. If a magnetic needle be accu
balanced and suspended so as to turn
in a vertical plane, the north pole will
pressed, and the south pole elevated
the horizon, this is called the *dip o
needle.*

464. A magnetical needle constr
for the purpose of shewing this prope
called a *dipping needle.*

465. When a piece of iron is br
sufficiently near a magnet, it becomes
a magnet.

466. Bars of iron that have stood lc
a perpendicular situation are generally
to be magnetical.

467. If a long piece of hard iron be
red hot, and then suffered to cool i
direction of the magnetical line, it be
magnetical.

468. The electric shock will often r
iron magnetical; so also will lightnin

469. Artificial magnets are made b
plying one or more powerful magne
pieces of hard steel.

470. The power of a magnet is not
nished, by communicating its prop
to other bodies.

471. Two or more magnets joine

gether may communicate a greater power to a piece of steel than either of them possesses singly.

472. A magnetic needle is made by fastening the steel on a piece of board, and drawing magnets over it, from the centre outwards.

Illustration. A magnetic needle is represented in figures 61 and 62: the first of which shews the upper side, and the second a side view of the needle, having a pretty large hole in the middle, to which a conical piece of agate is adapted by means of a brass piece O, into this the agate cap (as it is called) is fastened. The apex of the hollow cap rests upon the point of a pin F, which is fixed in the centre of the box, and upon which the needle, being properly balanced, turns very nimbly.

A mariner's compass, is represented in fig. 63. the box which contains the card or fly with the needle, is made of a circular form, and either of wood, or brass, or copper. It is suspended within a square wooden box B, by means of two concentric circles, called gimbalds, so fixed by cross axes *a*, *a*, *a*, *a*, fig. 64. to the two boxes, that the inner one, or compass box, shall retain an horizontal position in all motions of the ship, whilst the outer or square box is fixed with respect to the ship. The compass box is covered with a pane of glass, that the motions of the card may not be disturbed by the wind. What is called the card, is a circular piece of paper, which is fastened upon the needle, and moves with it. The outer edge of this card is divided into 360 equal parts or degrees, and within the circle of these divisions it is again divided into 32 equal parts or arcs, which are called the points of the compass, or rhombs, each of which is often subdivided into quarters.

END OF THE ENUNCIATIONS AND ILLUSTRATIONS.

QUESTIONS

And other Exercises on the foreg
Summary of Facts.

How is *matter* defined?
What are the inherent properties of ter?
What do you mean by *solidity*?
How is the definition illustrated?
What experiments prove this?
What do you infer from these ex ments?
What is meant by the *divisibility* of ter?
How is this definition illustrated?
What experiments shew the great e: to which divisibility may be carried?
What may be inferred from these ex ments?
What is meant by the *mobility* of ter;
How is the definition illustrated?

What is meant by the *inertness* of matter?

How is this definition illustrated?

What experiments prove the truth of this?

What is meant by *attraction*?

How many kinds of attraction are there?

What is meant by the attraction of *cohesion*?

To what is this attraction limited?

What experiments illustrate this sort of attraction?

What is *capillary* attraction?

By what experiments is capillary attraction illustrated?

What effect have different degrees of cohesion on bodies?

What is meant by *repulsion*?

Where does repulsion commence?

How is the repelling force illustrated?

What experiments shew the force of repulsion?

What is meant by the attraction of *gravitation*?

Why does a stone fall to the ground?

Towards what body do the planets gravitate?

Towards what point do all terrestrial bodies tend?

In what cases is the force of gravity equal?

In what part of the earth is it the least?

Where is it the greatest, and how does it decrease?

By what law does it increase?

How is *motion* defined?

Is motion an important agent in nature?

With what kinds of motion are we chiefly concerned?

How are these sorts of motion illustrated?

What experiments shew the particles floating in the air?

What are the things to be noticed with regard to motion?

What is the consequence of the inertness of bodies?

What are the motive powers?

How is the velocity of motion estimated?

How is the degree of velocity ascertained?

Give me some examples.

How is the space run over measured?

What is the reason of this?

Give me an example.

To what does a body in motion tend?

When is motion in a straight line: and when in a curve?

In what cases is motion in the same direction, in which the moving force acts?

What is meant by the composition of motion?

Look to figure 1, and shew how it is illustrated.

What examples are there to prove the existence of compound motion?

What is *accelerated* motion?

What is *uniformly* accelerated motion?

What examples prove it?

When is motion said to be retarded?

How are the velocities of falling bodies estimated?

How are the spaces estimated?

Explain this by fig. 2.

What is the corollary?

Through how many feet does a body fall in a second?

How is the force of a moving body estimated, and what is it called?

When are the momenta of bodies equal?

Illustrate this by experiments?

What is the inference drawn from this?

In what case is a curve produced by a moving body?

Produce an example.

What do you mean by the *centrifugal* force?

What is the *centripetal* force?

What are called the *central forces*?

What do you mean by the *centre of gravity*?

In what case will a body be at rest?

In what point is the weight of a body centered?

Where is the centre gravity of two or more bodies?

Explain this by fig. 3.

What is meant by the line of direction?

Why does a body stand or fall?

Explain this by fig. 4.

What is inferred from this?

When does a body stand most firmly?

In what case is a body easily overthrown?

In what cases does a body slide, and in what does it roll?

Illustrate this by fig. 5.

What are the examples given?

What are the mechanical powers and for *what* are they used?

Is every machine made up of these?

What circumstances are to be regarded in *treating* of mechanical engines? En

Enumerate the mechanical powers.

In what state is the power of a machine calculated?

What is a lever?

How many kinds of levers are there, and how are they distinguished?

How is the power gained in levers calculated?

Describe the lever of the *first* kind.

Mention some instances of levers of this kind.

To what purposes are levers of this kind applied?

Describe the lever of the *second* kind.

In what instances is it applicable?

Describe the lever of the *third* kind.

In what instances is this principle applicable?

Why are the wheels in watch-work reckoned levers of the third kind?

Shew how it is that the moveable bones of animals are constructed as levers of this kind. See fig. 11.

How is the loss of power compensated?

What is a hammer lever?

Explain this by figure 13.

Why does a hammer draw a nail easier than pincers?

What is to be allowed for friction in t application of the mechanical powers?

How do you explain the maxim, that wh is gained in power is lost in time?

What is the capital advantage of the m chanical powers?

What is the other advantage mentione

What are the principal moving power

What power is most easily applied a first mover?

Why is the weight used in slow mov ments?

In what respect is the spring like weight?

In what does it differ?

Mention the example given.

What is the most powerful agent?

To what is the force of running water a plied?

Why is running water preferable to wi as a mover of machines?

What is the strength of a man compa with that of a horse?

What do you mean by a pendulum?

What is meant by a vibration?

How are vibrations performed?

Are the vibrations slower in long or short pendulums?

What is the length of a pendulum that vibrates seconds?

Is the pendulum that vibrates seconds longer at the pole or at the equator?

What is the length of the pendulum that vibrates half seconds?

What is the length of a pendulum that vibrates once in two seconds?

How are the lengths of pendulums estimated?

What is the chief cause of the irregularity of clocks?

What do you mean by a fluid?

How are fluids divided?

Of what does hydrostatics treat?

To what laws are fluids subject?

In what do they differ from solids?

How do fluids press?

What experiments shews the upward pressure of fluids?

When is a fluid at rest?

How is the pressure of a fluid estimated?

Mention the experiments to prove this.

What pressure does the bottom of a vessel sustain?

Explain this by experiments and by the *figures* 25 and 26.

How is pressure estimated at the bottom

What

What inference is deduced from this?

What is meant by the hydrostatical paradox?

Illustrate this by experiment.

By what instrument is the upward pressure of fluids shewn?

Of what does the hydrostatical bellows consist?

What is meant by the specific gravities of bodies?

With what are bodies compared to obtain their specific gravities?

In what instance does a body sink in a fluid?

How much will a body lose of its weight when suspended in a fluid?

In what cases do bodies lose equal weights when suspended in fluids?

Why do bodies sink deeper in lighter than in heavier fluids?

When will a body remain at rest in a fluid?

When will a body sink in a fluid?

Can you explain by fig. 28. the use of the hydrostatic balance?

How is the specific gravity of a body found?

What do you mean by an *hydrometer*?

Of what use is the science of *hydraulics*?

What kinds of machines depend on it?

Upon

Upon what principle are fluids conveyed over hills?

What is the principle upon which fountains act?

Of what does the common pump consist?

Can you explain the principle by means of fig. 29?

What is meant by a forcing pump?

Explain the principle by fig. 30.

From what depth can water be raised by the common pump?

Is the forcing pump limited to any height?

For what is the air-vessel used?

How is a constant stream obtained?

Of what does the science of pneumatics treat?

Does the air surround the earth?

What do you mean by the atmosphere?

Why is the air not visible?

How is its existence ascertained?

Of what nature is the pressure of the air?

How is the pressure of the air discovered?

Is the air compressible?

What experiments prove it?

Is the air elastic, and what is the law that it follows?

What experiments prove the elasticity of the air?

What is wind?

For what are air pumps used?

Explain, by means of fig. 31, the structure of the air-pump.

How much heavier is water than air?

How is this ascertained?

In what cases are the surfaces of fluids at rest?

What will happen if the pressure be removed from any part?

Do you recollect the experiments that shew the pressure of the air?

To what is the pressure of the atmosphere equal?

By what means is the variation of the height of the mercury known?

Upon what principle is the barometer constructed?

What is the usual altitude of the barometer in London?

When the mercury is low what weather may be expected?

What causes the expansion of the air?

How is the air condensed?

How is the density of the air estimated

Describe the experiment by means of fig 33.

In what part of the atmosphere is the air the densest?

Is the exact height of the atmosphere *known?*

At what height is it incapable of refracting the sun's rays?

By what experiment is the resistance of the air to falling bodies shewn?

By what experiment is mercury forced into pores of wood?

Describe the experiment of the brass hemispheres.

Can a square phial be broken by the external pressure of the air?

How is the spring of the air shewn?

By what means can a phial be broken by the internal spring of air?

How is a shrivelled apple made to appear plump and healthy. Can the air in an egg be made to expand so as to force out all the contents?

How is beer made apparently to boil without the application of heat?

Why does smoke ascend?

Is air necessary to the propagation of sound?

Is air necessary to animal life?

What do you mean by an artificial fountain?

How is sound increased?

Can a phial be broken by means of condensed air?

Of what does the science of Acoustics consist?

Of what does Diacoustics treat?

Of what does Catacoustics treat?

In what state is a sonorous body while sounding?

What are the principal causes of the variety of sounds?

Upon what does the continuance of the vibrations of a sounding body depend?

Explain this by the example.

Shew me how it happens that the vibrations of a musical string are communicated to other parts of it, which might be supposed to be at rest; see fig. 36.

How fast does sound travel?

To what has the knowledge of the velocity of sound been applied?

Of what does light consist?

What is meant by a ray of light?

How much space will a candle fill?

At what rate does light travel?

How is it proved that the particles of light are incomprehensibly small?

What experiments illustrate this?

How do we attain the idea of light?

How

How do we get the visible idea of bodies
Illustrate this by experiment.

Does every point of a visible body reflect the rays of light?

How do the rays of light move?

What is the proof of this?

What is meant by a *pencil* of rays?

What is meant by a *medium*?

What is meant by *parallel* rays?

When are rays said to diverge?

When are they said to converge?

What is meant by a focus?

What is the imaginary focus?

In what cases is the passage of rays of light straight?

In what case do rays of light pass from one medium to another, in the same direction?

When are rays said to be refracted?

In what case are rays of light refracted *towards* a perpendicular? Explain this by fig. 38.

In what case are rays of light refracted *further from* the perpendicular? Explain this by the figure.

Shew me what fig. 39 is intended to prove.

What do you mean by a lens?

What is a plano-convex lens?

What is a plano-concave lens?

What is a double convex-lens?

What is a double concave lens?

What is a meniscus?

What is the axis of a lens?

What do you mean by the principal focus of parallel rays?

What is the focal distance?

To what is the focal distance of a *plano-convex* lens equal?

To what is the focal distance of a *double convex* lens equal?

How is the force of heat in a focus estimated?

Give me the illustration.

What are common burning glasses?

How does a globular decanter of water act?

Explain what is meant by fig. 41.

Where must a candle be placed for the rays to become parallel upon going out of the lens?

How must it be placed for the rays to *diverge*, and how to *converge*?

Where is the inverted image formed?

Explain what is meant by fig. 42.

Under what circumstance does the picture become larger or less than the object?

What do you mean by the imaginary focus?

Explain this by fig. 43.

What effect does a plano-concave lens *produce upon* parallel rays?

When are rays of light said to be reflected?

What do you mean by an incident ray?

Explain this by fig. 38.

What is the angle of *incidence*?

What is the angle of *reflection*?

What is the angle of *refraction*?

Explain these definitions by fig. 38.

What is a mirror?

Of what are mirrors made?

How many kinds of mirrors are there?

What are plane-mirrors?

To what is the angle of incidence equal?

Where will parallel rays meet after the reflection of a concave mirror?

Explain this by fig. 44.

Where will the image of a *celestial* object be found after the reflection of a concave mirror?

Where will the image of a *terrestrial* object be found after reflection from a concave mirror?

In what case is the image less than the object?

In what case is it larger?

When is the image equal to the object?

What remarkable appearance happens to a person standing before a concave mirror?

Is light a simple body?

How are the different colours examined?

Explain this by fig. 46.

Do you recollect the proportional parts of the different colours?

What effect is produced by mixing the primitive colours?

Are the seven colours reducible to a less number?

What is the most remarkable instance of the separation of the primary colours of light?

How is the rainbow formed?

Is it formed in any other other way than by drops of rain?

Of what is the eye composed?

What are the three coats?

What are the three humours?

Explain this by fig. 47.

How are objects seen?

Will you illustrate this?

Are the images of objects painted on the eye erect?

Upon what does dimness of sight depend?

For what are spectacles used?

For what eyes are concave glasses used?

Explain this.

When are convex glasses wanted?

Ex.

Explain the reason of this.
How near are objects seen distinctly ?

For what are microscopes used ?
Do they magnify objects ?
What experiment illustrates this ?
How many kinds of microscopes are there ?
What is the structure of the single microscope.
How is the magnifying power estimated ?
Explain the structure of the compound microscope.
How is the magnifying power of this estimated ?
Give me an example.
How is the object best seen ?
Upon what does the solar microscope depend ?
Of what is it composed ?
How does it act ?
How is the magnifying power estimated ?
Give me an example.
For what are telescopes used ?
Of what does the refracting telescope onsist ?
Do you see objects erect by this ?
How is its power estimated ?
Give me an example.

How

How is the refracting telescope constructed to shew objects erect?

How is the camera obscura constructed?

How is it made portable?

Explain this by fig. 49.

What is the structure of the magic lanthorn?

Explain this by the figs, 50 and 51.

What do you mean by a multiplying glass?

Explain its structure by fig. 52.

What do you mean by Astronomy?

What are the celestial bodies?

Of what figure is the earth?

How is it proved?

What is the sensible horizon?

What do you mean by the rational horizon?

Which way do the heavenly bodies appear to move?

Why is it called mid-day when the sun is at the meridian?

When you stand with your back to the north, how are the South, West, and East situated?

What do you mean by the equator?

How are the north and south poles of the earth situated?

In what time does the whole sphere of the heavens appear to revolve?

Does the sun always rise and set on the same points of the horizon?

What is meant by the ecliptic?

What is meant by the obliquity of the ecliptic?

What is the zodiac, and what does it include?

How does the sun appear to move?

What is meant by the tropics?

Of what does the solar system consist?

What are the names of the primary planets?

To which of the planets are there moons?

Explain the solar system by fig. 53.

How do the planets move?

What are the orbits of the planets?

Of what shape are these orbits?

What is meant by a planet's year?

How is the day of a planet measured?

How are the planets seen?

Which are the inferior planets, and why so called?

Why are the others called superior planets?

How is it known that Mercury and Venus go round the sun?

How is it known that their orbits are within that of the earth's?

When is a planet said to be in conjunction with the sun?

When is a planet said to be in opposition to the sun.

How many conjunctions have the planets in each revolution?

What is meant by the transit of a planet?

In what part of the orbit do the planets move faster, and in what slower?

How large is the sun?

How is it known that the sun turns on its axis?

What does Dr. Herschel think the sun is?

What is Mercury remarkable for?

For what is Venus remarkable?

When is Venus a morning, and when an evening star?

What do you mean by the transits of Venus and Mercury?

How is the Sun's distance ascertained?

How is the earth described?

What do you mean by the antipodes?

What two motions belong to the earth?

Of what is the diurnal motion of the earth, the cause, and why?

By what is twilight occasioned?

Is the axis of the earth inclined?

What does the inclination of the earth's axis occasion?

Ex-

Explain this by Plate IX.

What is the moon?

How far distant is it from the earth?

In what time does the moon perform her revolution?

What is the length of the moon's year, and day?

When is it new moon?

When is it full?

Explain the phases of the moon, by Plate X.

Is the earth a satellite to the moon?

How much larger does the earth appear to the moon, than she does to us?

How is the moon seen?

Upon what do her changes depend?

How is Mars known?

By whom was Ceres discovered?

When and by whom was Pallas first seen?

Who discovered Juno?

When was Vesta first seen?

For what is Jupiter remarkable?

How many moons are there belonging to Jupiter?

How are Jupiter's satellites eclipsed?

To what purposes have the eclipses of Jupiter's satellites been applied?

For what is Saturn remarkable?

How many satellites are there belonging to Saturn?

How is the Herschel planet seen?

In what respect are comets like planets?

How do they move?
When are they visible?
What appearance do they put on when they approach the sun?

Why are fixed stars so called?
How are they classed?
Why do they appear to the naked eye as innumerable?
How many are visible at once?
How are they divided?
How do they shine?
What is meant by the nebulæ?
For what purpose is each nebula destined?

When is a heavenly body said to be eclipsed?
What eclipses are the most striking?
Why does the earth cast a shadow behind it?
When does an eclipse of the moon take place?
At what time does it happen?
Why does it not occur every full moon?
When is an eclipse of the moon, full and when partial?
By what is an eclipse of the sun occasioned?

When

When does it happen?

Why does a small part of the earth only suffer an eclipse at one time?

What do you mean by an occultation?

Of what use are the occultations of the fixed stars?

To what are the ebbing and flowing of the sea owing?

What effect has attraction on the earth?

Where is the highest tide?

When is it highest?

Does the oval figure of the water keep pace with the earth?

Why are there two tides in about 25 hours?

What are spring tides?

What are neap tides?

Where is the electric fluid found?

Why is not this fluid commonly observed?

When is a body said to be electrified?

Can you mention the experiment that shews the effect of electricity?

What do you mean by conductors

What is meant by non-conductors? Which

Which are conducting substances?

Which are non-conducting substances?

Can all substances be made conductors?

When is a body said to be positively, and when negatively electrified?

When is a conductor said to be insulated?

What is a principal method of exciting the electric fluid?

Under what circumstances is the electric fluid most powerfully excited?

Mention the experiment.

When do substances *repel* each other?

When do substances *attract* each other?

Under what circumstances do the person that rubs the tube, and the tube itself, become electrified?

Can you mention the experiments?

Do the different electricities accompany each other?

In what respect do conductors differ from non-conductors?

If one side of a glass is positively electrified, in what state will the other be?

How can the two electricities be brought together?

What is the electric shock?

Can you explain the structure of an electrical machine, fig. 54.?

When

When do electrified bodies repel each other?

What experiments prove this?

What do you mean by an electrometer?

Explain its structure by fig. 55.

In what case is the electric spark visible?

How is the equilibrium restored?

What do you mean by the electric shock?

Is the motion of electricity very rapid?

What happens when one side of a glass is electrified?

Prove this by the experiment.

Does the electric fluid spread on glass?

How is it communicated to the whole surface of the glass?

How is electrified glass discharged?

What shaped glasses are used in electricity?

What is the Leyden phial?

Explain its structure by fig. 56.

Mention the experiment performed by this?

What do you mean by an electrical battery?

Explain how it is used, fig. 57.

What experiments can be performed by the electrical battery?

In what way are buildings defended from lightning?

When does electricity put on the appe ance of a star, and when a brush?

Can instruments be put in motion by t electric fluid?

What is lightning?

What is thunder?

What is the aurora borealis?

Upon what do earthquakes, &c. depend

What is meant by the science of Galva ism?

What is the difference between electrici and Galvanism?

What parts of animals are most easi affected by the Galvanic fluid?

By whom was Galvanism discovered?

How did Galvani discover it?

Can motions be produced in dead anima by means of galvanism?

What experiments prove this?

How are conductors divided?

Which are the perfect conductors?

Which are imperfect conductors?

What is the most simple Galvanic com bination?

When is the combination of the first, an when of the second order?

What is requisite in Galvanic circles?

Give the example of a pile of the first orde

In what state is the extremes of a electric?

Can the Galvanic effects be increased ?

Explain by fig. 58. the nature of a Galvanic battery,also that represented by fig.59.

How can the Galvanic shock be given ?

Shew me,by fig. 60. how any combustible substances can be inflamed ?

What facts are explained by Galvanism ?

What is meant by magnetism ?

To what bodies can magnetic properties be communicated ?

Do all magnets attract iron ?

To what point does a magnet at liberty move ?

What are the poles of the magnet ?

What is the directive power ?

What is the magnetic meridian ?

What is the declination of the magnet ?

In what cases do repulsion and attraction take place ?

What is meant by the dipping of the magnetic needle ?

Can magnets be made to impart their properties ?

When is iron attracted by the magnets ?

Which is attracted most powerfully ,iron or steel ?

How is the magneticpower weakened,and *how destroyed ?*

Ho

How is the magnetic power increased ?

In what cases is the magnetic power m powerful ?

When will a magnet place itself in magnetic meridian ?

How is it applicable to the steerin ship ?

What is the mariner's compass ?

What do you mean by the angle of de nation ?

When is the declination *east* or *west* ?

What is the declination now ?

What is meant by the dip of the need

What is a dipping-needle ?

In what case does iron become magne

In what situation do iron bars bec magnetical ?

What effect has lightning upon iron ?

How are artificial magnets made ?

Is the power of the magnet diminis by communicating its properties to o bodies ?

How is the magnetic needle made ?

Explain the structure of the magn needle by fig. 61, and 62.

Explain the structure of the mari compass, by fig. 63.

GLOSSARY

OF TERMS USED IN THIS VOLUME.

ACCELERATED, one increase of swiftness continually added to a former increase.

Accoustics, the science that treats of sound in general.

Action, the power of one body exerted on another.

Acute, sharp ; ending in a point; the highest sound of an instrument.

Adhesion, the union of two bodies simply touching each other.

Adulterated, the mixture of some base matter.

Affinity, a term used to express that property which different species of matter have to unite with each other.

Air-pump, a machine by which the air contained in bodies may be exhausted. See p. 42.

Amalgam, a mixture of mercury with some other metal, as tin, &c.

Analogous, bearing some resemblance or proportion.

Analysis, the resolution of a substance into its constituent parts.

Angle

Angle, the ends of two lines inclining to, and r ing each other, form an opening or co called an angle.

Animalculæ, the smallest of all possible ins which without the help of glasses, e the most piercing eye.

Apex, top, point, or summit.

Aphelion, the greatest distance of a planet the sun.

Apogee, the sun's or moon's greatest distance the earth.

Apparatus, things to be provided for the pu of experiments.

Aqueducts, conveyances for water.

Astronomy, the science which relates to the c tial bodies.

Atmosphere, the air that surrounds the globe c earth.

Atoms, the most minute and invisible par which bodies are formed.

Axis, a direct line passing through the centr any body on which it may turn.

Balance, lever of the first kind, p. 19.

——— hydrostatical, p. 37.

Barometer, an instrument which shews the vari of the pressure of the atmosphere. See p

Battery, electrical, p. 98.

Bellows, hydrostatical, p. 35.

Bodies, all those things which can be called stances, have a shape or form, and m felt or known by the senses.

Capacity, the quantity of room that a body h receive other bodies within it.

Capillary tubes, small tubes resembling hai their capacities.

Cardinal point, one of the four principal poin

the compass; the north, south, east and west, are the four cardinal points.

Catoptrics, that part of optics which treats of vision by reflection.

Cause, that which produces an effect.

Centre of gravity, a point of a body, on which, when suspended, it will rest.

Choroides, one of the coats of the eye.

Cohesion, the force inherent in all substances which prevents them from falling to pieces.

Combination, the different ways that quantities or substances may be varied in order to produce a new form.

Compass, an instrument dividing the horizon into 32 equal parts; by this instrument mariners steer their course. See p. 109.

Composition, a mixture of different ingredients to constitute one whole.

Compound, a substance made up of many ingredients.

Concussion, the act of bringing the parts of a body nearer to each other.

Concave, a regular curved hollow.

Condensation, the same with compression.

Contraction, that kind of motion which makes a body shorten itself.

Converging rays, rays which incline towards each other till they meet in a point.

Convex, a round form like the top of a watch-glass; as a concave is hollow, like the inside of a watch-glass.

Cornea, the second or horny coat of the eye, containing the watery humour.

Corpuscula, the smallest of all bodies.

Cubic inch, is an inch square, made into a solid body like a die, whose length, breadth and depth are equal.

Cylinder, a body having two flat surfaces and one circular;

circular; a tube or pipe completely round and uniform from one end to the other, is a cylinder.

Density, thickness; or that property by which bodies contain a certain quantity of matter under a certain bulk; so that more matter under the same bulk is greater density.

Diagonal, a line drawn from angle to angle, and dividing a square into equal parts.

Diameter, a straight line passing through the centre of a circle.

Diaphanous, transparent, allowing the light to pass through, as glass, air, water, &c.

Dilatation, the act of becoming thin and wide, so as to preserve the same quantity of matter, but to acquire a larger volume; contrary to contraction.

Dimension, the measure of a body, either as it is long, broad, or deep.

Dioptrics, that part of optics which treats of the different refractions of light passing through different mediums, as air, water, glass, &c.

Disk, the face of the sun or moon being round, and appearing to our sight as flat.

Divergent rays, rays which, going from the point of any visible object, depart from each other.

Divisibility, see p. 2.

Ductility of metals, the quality that metals have of becoming flexible, pliable, and of being extended.

Effervescence, an intestine motion which takes place in certain bodies, occasioned by the escape of the gaseous substance.

Effluvia, the small and insensible particles that fly off from bodies.

Elasticity, the power which a body has to return

to

to its first situation, as a cane that is forcibly bent flies back again.

Electrical, bodies which have the power of attracting light substances to them without magnetism: amber, sealing-wax, &c. when excited by friction are of this description.

Elements, the original, unmixed, simple parts of bodies, which are incapable of decomposition.

Emanation of Light, flowing round in all directions, from a source or centre, as the rays of light from a taper or from the sun.

Equilibrium, equipoise, equality of weight at each end.

Evaporation, the conversion of fluids into vapour by heat.

Exhale, throwing forth vapours, from the surface only.

Expansion, the swelling or increase of bulk.

Experiment, a trial made on natural bodies for the purpose of discovering their qualities or their properties, and ascertaining their causes and effects.

Faces, small surfaces; a superficies cut into several angles.

Fibres, fine ligaments or strings, tough and long, the middle part of which is very fleshy.

Filaments, thin, slender threads; also small fibre which make up the texture of the muscles.

Fluids, any thing not solid; bodies which are supposed to be made up of particles so very small and round, that they are easily [illegible] in motion.

Finite, that which has an end; it also means [illegible] terminate.

Focus, the point wherein the rays are collected after they have undergone refraction or reflection.

Foci, plural of focus.
Form, the external appearance or shape of any thing.
Frangible, easily broken.
Friction, the rubbing of two or more bodies against each other.
Fulcrum, a prop.
Fusion, the act of melting, the state of being melted.
Galvanism, see p. 100.
Gas, all solid substances when converted into permanently elastic fluids by means of heat, are called gases.
Globules, small round bodies.
Grain, the weights here following are generally used in the experiments of natural philosophy.

One pound contains 12 ounces, or 240 pennyweights, or 5,760 grains.

One ounce contains 20 pennyweights, or 480 grains.

One pennyweight contains 24 grains.

Gravity, weight, heaviness, tendency to the centre.
——— specific, see p. 36.
Hemisphere, the half of a globe, or sphere.
Heterogeneous, consisting of parts unlike each other.
Horizon, the line that terminates our view of the sky.
Horizontal, level with the horizon.
Humours, parts of the eye, of which there are three, the *aqueous*, the *crystalline*, and the *vitreous*; see p. 63.
Hydraulics, the science that teaches how to estimate the force of fluids in motion.
Hydrometer, an instrument for obtaining the specific gravities of liquids.
Hydrostatics, the science which treats of the nature, gravity, pressure and motion of fluids, and of weighing solids in them. See p. 32.

Hypothesis, supposition; principle laid down, and to be taken for granted.

Igneous, the property of those bodies which communicate fire.

Impelled, pushed or driven onwards.

Inch square, is a portion of any substance of four equal sides, every one of which is an inch in length.

Inclined Plane, a surface that slopes or inclines to the level of the horizon: one of the mechanical powers. See p. 25.

Inertness, the state of being quite still.

Infinite, without end; indeterminate.

Inflexibility, incapable of being bent.

Integrant parts, are those which collectively make up a whole body.

Interstice, space between one thing and another.

Layer, a thin covering of any one substance spread upon another.

Lens, a glass made of a peculiar shape. See p. 54.

Lever, any contrivance to enable us to raise a body that is either too heavy or too inconveniently placed to be raised by the mere strength of the arm: one of the mechanical powers. See p. 18.

Line of direction, is that line which proceeds from the centre of gravity to the earth.

Magic lanthorn. See p. 70.

Matter, is every substance that may be felt, divided, put in motion, or stopped, and is extended in length, breadth, and depth.

Mechanical powers. See p. 17.

Medium, any substance through which bodies move, as air, water, vapour, &c.

Media, plural of medium.

Microscope, an instrument by means of which the most minute objects are made apparent to

the eye, and every part distinctly. See p. 66.

Mirror, any polished body that forms images of objects by reflection. See p. 59.

Moving Powers, see p. 29.

Muscles, the principal organs or promoters of motiôn in all animated bodies.

Non-elastic, bodies that do not restore themselves to their former figures after having been struck or bent by other bodies.

Oblique, aslant, or forming an angle with the perpendicular line.

Obtuse, blunt, the contrary to acute.

Oleaginous, partaking of the nature of oil.

Opacity, cloudiness: want of transparency.

Opaque, dark, obscure, cloudy, the contrary to transparent.

Optics, the science which explains the properties of light. See p. 50.

Organ, the instrûment of some faculty; thus the eye is the organ of sight.

Parallel, lines are parallel to one another, when they are every where equally distant from each other.

Particles, the very smallest points or atoms that can be conceived to enter into the composition of bodies.

Pendulum. See p. 31.

Physics, natural philosophy, or that science which treats of the powers and properties of bodies in their natural state.

Plane, a flat surface, level with the horizon.

Pneumatics, the doctrine of the air; and of the effects dependent on its properties. See p. 4.

Plane, inclined, one of the mechanical powers. See p. 24.

Pores, small openings found between the particles of all bodies.

Prism, a prism of glass is a glass bounded with two equal and parallel triangular ends, and three plane sides. See p. 61.

Process, the way of proceeding in, and conducting any experiment.

Proportion, comparative relation of one thing to another; ratio.

Pulley, one of the mechanical powers. See p. 23.

Pump. See p. 38.

——— *forcing*. See p. 39.

Pyrometer, an instrument for ascertaining the expansion of solid bodies by heat.

Quality, the property by which one thing is distinguished from another.

Quantity, that property of any thing which may be increased or diminished.

Quotient, in arithmetic, the number produced by the division of two given numbers one by the other.

Rarefaction, the same with dilatation.

Ray, a beam of light emitted from a luminous body.

Radius, a line which proceeds from the centre of a circle, and ends in its circumference.

Recipient or receiver, that part of the air-pump, which incloses the bodies that are put therein.

Reflection of the rays of light, is their return, after their approaching so near the surfaces of bodies as to be driven backwards.

Refraction of the rays of light, is when they pass obliquely out of one medium into another.

Relation, the connection that two quantities have to each other with regard to their size or magnitude.

Repulsion, a principle whereby the particles of bodies are prevented from coming into actual contact.

Retarded, velocity or swiftness continually diminished.

Retina, the expansion of the optic nerve, on the inner surface of the eye, is so called from its resemblance to a net.

Reverberation, the act of a body repelling another after its striking on it.

Rotation, a wheeling round itself.

Science, a clear, obvious, and certain knowledge of things founded on truth.

Scintillation, sparkling ; the trembling and twinkling motion of the stars.

Sclerotica, one of the coats of the eye.

Screw, one of the mechanical powers, see p. 27.

Simple bodies, the same with elements.

Sine, a right line drawn from one end of an arch, perpendicularly upon the diameter drawn from the other end of that arch.

Siphon, an incurvated chemical tube or pipe.

Solar, belonging to or proceeding from the sun.

Solids, the parts containing the fluids; hard bodies having length, breadth, and thickness.

Solution, the perfect union of a solid substance with a fluid.

Space, room, local extension, any quantity of place or of time.

Spectrum. see p. 62.

Sphere, a globe ; a body of which the centre is at the same distance from every point of the circumference.

Substance, being; something existing; solid, not empty ; that which makes a being perceivable by the senses.

Superficies, the whole of the outward parts of bodies ; surfaces.

Surface, superficies, outside; that of which we only consider the length and breadth.

Syringe, a pipe through which any liquor is squirted.

Tangent, a line that just grazes the surface of a

circle, or touches it in only one point.

Telescope, an instrument for viewing distant objects. See p. 68.

Tension, a bending or stretching out by the force of another body; the state of being stretched.

Tenuity, thinness; smallness, minuteness.

Texture, the manner in which the elements of any particular body are interwoven with each other.

Thermometer, an instrument to shew the relative heat of bodies.

Vaccuum, a space unoccupied by matter.

Vapours, the minutest particles of any fluid raised into the air by means of heat.

Velocity, swiftness; the property of a moving body to run over a certain quantity of space in a certain portion of time.

Vertical, in a direction perpendicular to the horizon.

Vibration, the quivering of a musical string with quick or slow motion, producing sound.

Vitrify, to be changed into glass.

Void, a vacuity or space wherein nothing is contained.

Volatile, bodies that are apt to evaporate are said to be volatile.

Volume, the quantity of room that any substance or body takes up in space.

Vortex, a fluid of any kind, in which the suction is circular.

Undulation, a motion like that of the waves, waving to and fro in the air.

Unison, one and the same sound; the agreement of two notes or strings of an instrument in one and the same tone.

Water, a transparent elementary liquid, tasteless, without colour or odour.

Wedge, one of the mechanical powers, a body with a sharp edge. See p. 26.

Week, contains 7 days, 168 hours, or 10,080 minutes.

Wheel and Axis, one of the mechanical powers. See p. 22.

Zenith, the point in the heavens over head.

Zodiac. See p. 74.

Zone, a division of the earth, with respect to the different degrees of heat found in different parts; there are the *torrid*, the two *temperate*, and the two *frigid* zones.

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